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ABSTRACT

A computer-based system model for the monitoring and management of the instructional process was conceived, developed and refined through the techniques of systems analysis. This report describes the various aspects and components of this project in a series of independent and self-contained units. The first unit provides an overview of the entire system--the approach, objectives, and procedures. A system approach to computer-managed instruction as a vehicle for accountability and evaluation in education is presented in the second unit, and the third unit describes the Adaptive Instructional Management System (AIMS) which provides computer management for the model courses of the project. Unit four the Empirical Course Development Model, is an instructional manual for the construction of individualized, self-paced, self-healing, multimedia instructional systems. An objective classification hierarchy which is predictive of student performance is evaluated in the fifth unit. Units six and seven examine the capability of AIMS to individualize and optimize instruction, and the eighth and ninth units report on two different model courses. The final unit introduces a major derivative and expansion of the original system and refers to dissemination and use of the project. (Author/SH)

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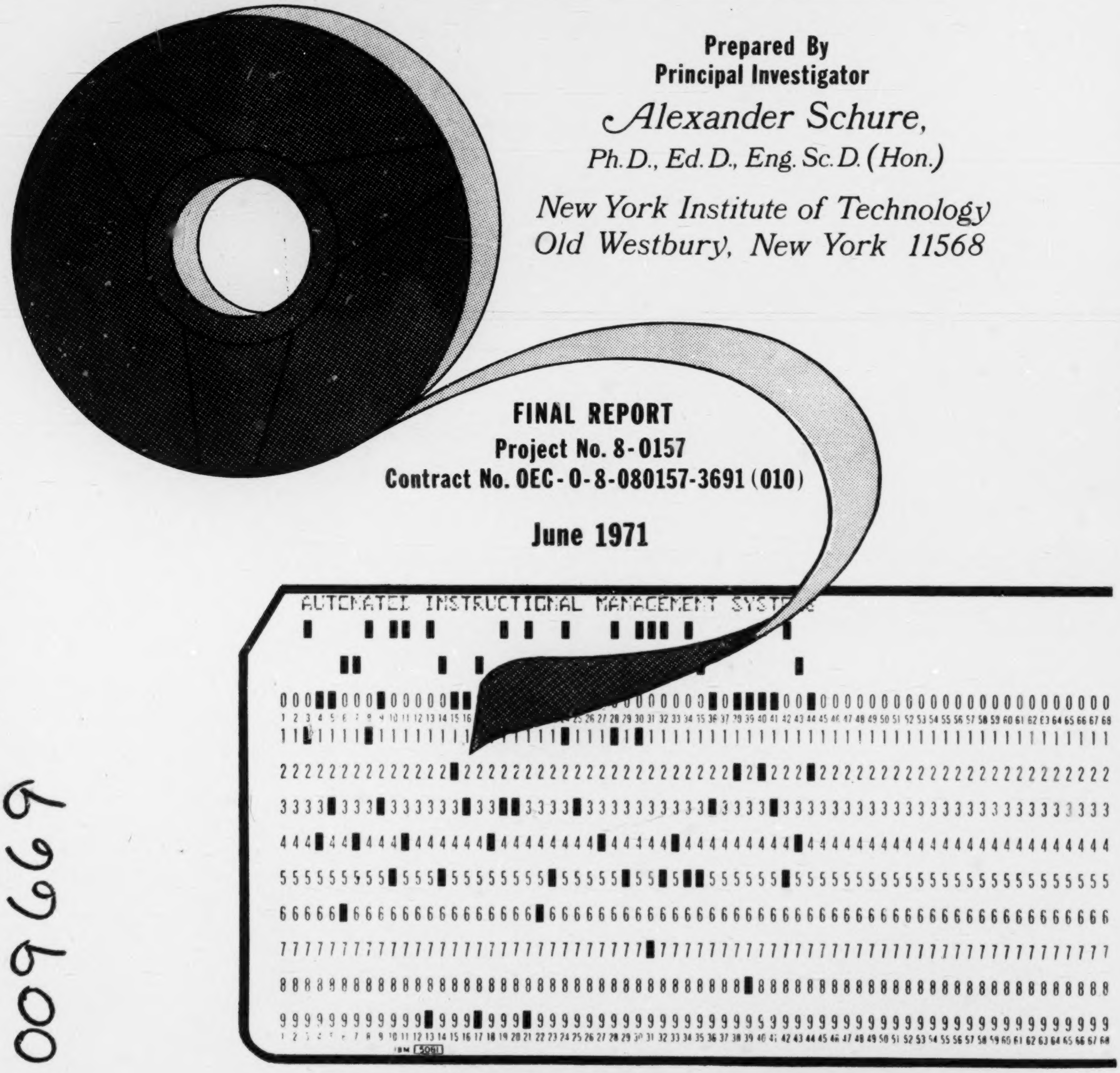
# A SYSTEM FOR THE INDIVIDUALIZATION AND OPTIMIZATION OF LEARNING THROUGH COMPUTER MANAGEMENT OF THE EDUCATIONAL PROCESS


AUTOMATED INSTRUCTIONAL MANAGEMENT SYSTEM
IBM 5081

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**FINAL REPORT**
**Project No. 8-0157**
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**U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE**
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# A SYSTEM FOR THE INDIVIDUALIZATION AND OPTIMIZATION OF LEARNING THROUGH COMPUTER MANAGEMENT OF THE EDUCATIONAL PROCESS

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
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Prepared By
Principal Investigator

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The research reported herein was performed pursuant to a contract with the Office of Education, U. S. Department of Health, Education and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the contract of their project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U. S. DEPARTMENT OF
HEALTH, EDUCATION AND WELFARE

Office of Education
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CONTENTS

Page

FOREWORD . . . . . . . . . . . . . . . . . . . . . . . . . . xi

ABSTRACT . . . . . . . . . . . . . . . . . . . . . . . . . . xiii

*UNIT 1*
*THE OVERALL SYSTEM*

I. DISCUSSION OF APPROACH: A GOVERNING PHILOSOPHY . . . . . . 1

II. SCOPE . . . . . . . . . . . . . . . . . . . . . . . . . 3

III. SPECIFIC OBJECTIVES OF THE ADAPTIVE INSTRUCTIONAL MANAGEMENT SYSTEM . . . . . . . . . . . . 4

IV. PROCEDURES . . . . . . . . . . . . . . . . . . . . . . 5

*UNIT 2*
*SYSTEMS APPLICATION IN HIGHER EDUCATION*

I. OVERVIEW . . . . . . . . . . . . . . . . . . . . . . . . 1

II. THE NEED FOR SYSTEMS RELATED INFORMATION . . . . . . . . . . 1

  A. Rationale . . . . . . . . . . . . . . . . . . . . . . 1
  B. Systems Related Information Yields - The Accountability Process . . . . . . . . . . . . . . . 2
  C. Characteristics of the Accountability Design . . . . . . . . . . . . . . . . 4

III. THE OVERALL DESIGN MODEL AND HOW IT OPERATES . . . . . . . . . . . . . . . . . . . . . 5

A. The Generalized Educational Management System . . . . . . . . . . . . . . . . . . . . . 5
B. System Objectives . . . . . . . . . . . . . . . . . . . . . 8
C. The Sequential Access File Entry Subsystem . . . . . . . 9
D. The Generalized Simulator . . . . . . . . . . . . . . . . 9
E. The Automated Instructional Management System . . . . . . . . . . . . . . . . . . . 10
F. Additional Evaluative System Characteristics . . . . . . . . . . . . . . . . . . . 16
G. The Guidance Model . . . . . . . . . . . . . . . . . . . 18
H. The Institutional Management Information System . . . . . . . . . . . . . . . . . . . 23
I. The Program Management Information System . . . . . . . . . . . . . . . . . . . . 23

IV. CONCLUSION . . . . . . . . . . . . . . . . . . . . . . . . 26

*UNIT 3*
*AUTOMATED INSTRUCTION MANAGEMENT SYSTEM*

I. OVERVIEW . . . . . . . . . . . . . . . . . . . . . . . . . 1

II. AIMS III STATUS . . . . . . . . . . . . . . . . . . . . . 2

III. GENERAL OBJECTIVES . . . . . . . . . . . . . . . . . . . 3

IV. REVIEW OF INFORMATION PRODUCED . . . . . . . . . . . . . 4

V. INPUT REQUIREMENTS . . . . . . . . . . . . . . . . . . . 11

VI. DESCRIPTION OF OUTPUT . . . . . . . . . . . . . . . . . 12

VII. THE CURRENT STATUS OF OPERATIONS OF AIMS III . . . . . . . . . . . . . . . . . 22

VIII. CONCLUSION AND EXTENSION . . . . . . . . . . . . . . . 24

IX. DEVELOPMENT OF PREDICTOR EQUATIONS . . . . . . . . . . . 25

X. SIMULATION LOGIC . . . . . . . . . . . . . . . . . . . . 32

XI. DOCUMENTATION AVAILABILITY . . . . . . . . . . . . . . . . . . . . . 33

APPENDIX . . . . . . . . . . . . . . . . . . . . . . . . . . 34

GLOSSARY . . . . . . . . . . . . . . . . . . . . . . . . . . 50

## *UNIT 4*
## *THE EMPIRICAL COURSE DEVELOPMENT MODEL*

EXPLANATION OF THIS REPORT, PURPOSE, FORMAT, AND USE . . . . . . . 3

GENERAL DESCRIPTION OF THE MODEL . . . . . . . . . . . . . . . . . 7

PHASE I: IDENTIFICATION AND STRUCTURING OF COURSE OBJECTIVES

A. Overview of Phase I . . . . . . . . . . . . . . . . . . . 12
B. Abbreviated Descriptions of Procedures . . . . . . . . . . . 15
C. Detailed Procedural Steps . . . . . . . . . . . . . . . . . 16
D. Procedural Flowchart . . . . . . . . . . . . . . . . . . . . 22

PHASE II: COURSE DESIGN

A. Overview of Phase II . . . . . . . . . . . . . . . . . . . 23
B. Abbreviated Descriptions of Procedures . . . . . . . . . . . 26
C. Detailed Procedural Steps . . . . . . . . . . . . . . . . . 27
D. Procedural Flowchart . . . . . . . . . . . . . . . . . . . . 36

PHASE III: COURSE MANAGEMENT AND MAINTENANCE

A. Overview of Phase III . . . . . . . . . . . . . . . . . . 37
B. Abbreviated Descriptions of Procedures
Section One: Management of Course Implementation . . . . 40
Section Two: Analysis of Results and Revision Decisions . . . . . . . . . . . . 42
C. Detailed Procedural Steps
Section One: Management of Course Implementation . . . . 44
Section Two: Analysis of Results and Revision Decisions . . . . . . . . . . . . 61
D. Procedural Flowcharts . . . . . . . . . . . . . . . . . . . 73

SUPPLEMENT: Special reference article, additional miscellaneous procedural guides, etc. . . . . . . . . . . . . . . . . . 75

REFERENCES . . . . . . . . . . . . . . . . . . . . . . . . . 97

## *UNIT 5*
## *COMPLEXITY OF LEARNING OBJECTIVES*

I. INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . 1

II. DEFINING LEARNING OBJECTIVES . . . . . . . . . . . . . . . . 2

III. CLASSIFYING LEARNING OBJECTIVES . . . . . . . . . . . . . . 6

IV. THE HIERARCHY DEFINED . . . . . . . . . . . . . . . . . . . 9

V. THE EXPERIMENT . . . . . . . . . . . . . . . . . . . . . . . 11

VI. CALCULATIONS AND RESULTS . . . . . . . . . . . . . . . . . . 12

VII. DISCUSSION . . . . . . . . . . . . . . . . . . . . . . . . 16

## *UNIT 6*
## *INDIVIDUALIZED INSTRUCTION AND THE MANAGEMENT SYSTEM*

INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . . . 1

CHARACTERISTICS . . . . . . . . . . . . . . . . . . . . . . . . 1

CONCLUSION . . . . . . . . . . . . . . . . . . . . . . . . . . 13

## *UNIT 7*
## *A RESEARCH DESIGN TO TEST THE SYSTEM*

I. A RESEARCH DESIGN TO TEST THE SYSTEM . . . . . . . . . . . . . 1

  A. Scope . . . . . . . . . . . . . . . . . . . . . . . . . . 1
  B. The Problem and Subordinate Problems . . . . . . . . . . . 1
  C. Definition of Terms . . . . . . . . . . . . . . . . . . . 2
  D. Delimitations . . . . . . . . . . . . . . . . . . . . . . 8
  E. Assumption . . . . . . . . . . . . . . . . . . . . . . . . 9
  F. Hypotheses . . . . . . . . . . . . . . . . . . . . . . . . 9

II. METHODS AND PROCEDURES . . . . . . . . . . . . . . . . . . . . . . . . 10

A. The Setting and Subjects . . . . . . . . . . . . . . . . . . 11
B. Data Collection on Learning Characteristics . . . . . . 12
C. The Course: Content and Structure . . . . . . . . . . . 13
D. The Instructional Media . . . . . . . . . . . . . . . . . . 15
E. The Conduct of the Experiment . . . . . . . . . . . . . 15

III. AIMS APPLIED TO THE DATA PROCESSING COURSE . . . . . . . . . . 16

A. The Data Storage Routines . . . . . . . . . . . . . . . . 16
B. The Data Collection Routines . . . . . . . . . . . . . . . 18
C. The Data Analysis Routines . . . . . . . . . . . . . . . . 18

IV. RESULTS . . . . . . . . . . . . . . . . . . . . . . . . . . . . 23

A. The Identification of Characteristics Related to Success and Failure with Specific Instructional Material . . . . . . . . . . . . . . . . . . 23
B. The Selection and Construction of Alternative Instructional Materials: Application of Experimental Results . . . . . . . . . . . . . . . . . . 28
C. Effect of the Computer Management System on Student Performance . . . . . . . . . . . . . . . . . 31

V. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS . . . . . . . . . 33

VI. REFERENCES . . . . . . . . . . . . . . . . . . . . . . . . . . 47

## *UNIT 8*
## *THE PROGRAMMED MATHEMATICS CONTINUUM*

I. STATUS . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1

II. DESCRIPTION . . . . . . . . . . . . . . . . . . . . . . . . . 1

A. Purpose . . . . . . . . . . . . . . . . . . . . . . . . . . 1
B. Scope . . . . . . . . . . . . . . . . . . . . . . . . . . . 1
C. Instructional Modes . . . . . . . . . . . . . . . . . . . 2
D. Self-Pacing . . . . . . . . . . . . . . . . . . . . . . . . 2
E. Individualization . . . . . . . . . . . . . . . . . . . . 2
F. Computer Interface . . . . . . . . . . . . . . . . . . . . 2
G. Computer Articulation . . . . . . . . . . . . . . . . . . 3
H. Criterion Checks . . . . . . . . . . . . . . . . . . . . . 5
I. Remediation . . . . . . . . . . . . . . . . . . . . . . . . 7
J. Optimization . . . . . . . . . . . . . . . . . . . . . . . 9

III. EVALUATION . . . . . . . . . . . . . . . . . . . . . . . . . 12

IV. SUPPORT MATERIAL . . . . . . . . . . . . . . . . . . . . . . . 15

- A. Software . . . . . . . . . . . . . . . . . . . . . . . . . 15
- B. The Handbook . . . . . . . . . . . . . . . . . . . . . . . 17

V. UTILIZATION OF THE SYSTEMS ANALYSIS APPROACH . . . . . . . . . 19

VI. THE DEVELOPMENT OF THE PMC SYLLABUS . . . . . . . . . . . . 22

VII. EVOLUTION OF THE MBO LIST . . . . . . . . . . . . . . . . . 27

- A. Original Terminal Objectives . . . . . . . . . . . . . . . 27
- B. A Structured List of Objectives . . . . . . . . . . . . . 27
- C. Combined Listing . . . . . . . . . . . . . . . . . . . . . 29
- D. Revised and Enlarged MBO List . . . . . . . . . . . . . . 31
- E. Concept Catalog . . . . . . . . . . . . . . . . . . . . . 32

VIII. HISTORY AND OPERATIONAL EXPERIENCE . . . . . . . . . . . . . 33

- A. Development of the Preliminary Computer Program Title: VICAR (Variable Input Computer Assembled Records) . . . . . . . . . . . . . . 33
- B. Installation and Replication Experience . . . . . . . . . 34
- C. Conclusions Derived from the Several Course Operations . . . . . . . . . . . . . . . . . 39
- D. Development of the SIM/AIMS Mode . . . . . . . . . . . . 41

GLOSSARY . . . . . . . . . . . . . . . . . . . . . . . . . . 47

FLOWCHARTS EXPLAINING THE SIMS/AIMS MODE OF COURSE OPERATION . . . . . . . . . . . . . . . . . . . . 52

## *UNIT 9*
## *ARTICULATED MULTIMEDIA PHYSICS*

I. ORIGIN OF COURSE MATERIALS . . . . . . . . . . . . . . . . . . 1

II. STATUS . . . . . . . . . . . . . . . . . . . . . . . . . . . 5

III. COURSE DESCRIPTION . . . . . . . . . . . . . . . . . . . . . 5

- a. General Objectives . . . . . . . . . . . . . . . . . . . . 5
- b. Scope of the Course . . . . . . . . . . . . . . . . . . . 6

c. Instructional Media . . . . . . . . . . . . . . . . . . 6
d. Instructional Strategies . . . . . . . . . . . . . . . . 7
e. Analysis of Subject Matter . . . . . . . . . . . . . . . 8

IV. EVALUATION . . . . . . . . . . . . . . . . . . . . . . 9

V. SUPPORTING MATERIAL . . . . . . . . . . . . . . . . . . 13

VI. DESIGN AND PROCEDURE HANDBOOK . . . . . . . . . . . . . 16

*UNIT 10*
*SYSTEM FOR PUPIL AND PROGRAM*
*EVALUATION AND DESIGN*

I. INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . 1

II. SPECIFIC PARTS OF THE SPPED . . . . . . . . . . . . . . 4

III. EVALUATION MODELS . . . . . . . . . . . . . . . . . . 8

IV. TRAINING . . . . . . . . . . . . . . . . . . . . . . . 10

V. ORGANIZATIONAL STRUCTURE . . . . . . . . . . . . . . . . 12

VI. DATA PROCESSING . . . . . . . . . . . . . . . . . . . . 15

VII. FUTURE DEVELOPMENTS . . . . . . . . . . . . . . . . . 15

VIII. LIMITATIONS . . . . . . . . . . . . . . . . . . . . . 17

DISSEMINATION AND VISITATIONS . . . . . . . . . . . . . . . 18

## FOREWORD

This research project, conceived and developed at the New York Institute of Technology, Old Westbury, New York, was initiated May 1, 1968, for a three-year term under the authority of P. L. 83-152, Title III, section 302 (c)(15), and P. L. 83-531 as amended by P. L. 89-10, Title IV, section 2(a), by the Office of Education of the Department of Health, Education and Welfare.

The principal Investigators for the New York Institute of Technology, Old Westbury, New York, were:

Dr. Alexander Schure, President

Dr. John Theobald, Executive Vice-President, and

Dr. Bertram Spector, Vice-President for Research

Project Director: Dr. Theodore Steele

Technical Director: Mr. J. Ward Harrigan

The sub-task leaders:

| | |
|---|---|
| Computer programming and operation: | Ernest O'Dierno |
| Articulated Multi-Media Physics: | Harvey Pollack |
| Programmed Mathematics Continuum: | J. Ward Harrigan |
| Introduction to Data Processing and Evaluation of the System: | Dr. Barbara Weinschel |

The chapters of this report are independent and self-contained units addressing various aspects and components of the project.

Unit 1 provides an overview of the entire system; the approach, objectives and procedures.

Unit 2 presents a system approach to computer managed instruction as a vehicle for accountability and evaluation in education. The present project is viewed as an important, though restricted, component in this broad plan.

Unit 3 describes the Adaptive Instructional Management System which provides computer management for the model courses of the project.

Unit 4, The Empirical Course Development Model, is an instruction manual for the construction of individualized, self-paced, self-healing, multi-media instructional systems. It represents a distillation of the experience gained in applying the systems approach to develop the model programs.

Unit 5 introduces and evaluates an objective classification hierarchy based on the complexity of hard science objectives. This classification method is of great importance to course development and management because it is highly predictive of student performance.

Unit 6 describes an investigation of the effectiveness of the Adaptive Instructional Management System to individualize instruction.

Unit 7 examines the capability of the Adaptive Instructional Management System to optimize instruction.

Unit 8 reports on the Programmed Mathematics Continuum, a model computer managed, self-paced, and individualized course of instruction.

Unit 9 is a presentation of the Articulated Multi-media Physics program, another model course directed by computer management. (A third computer-managed program, Self-Paced Physics, developed for the U. S. Naval Academy of Annapolis, is reported in detail in T. R. 5.10, Contract #N00600-68C-0749. A brief description is given in Unit 5.)

Unit 10 introduces a major derivative and expansion of the original management system. This generalization subsumes the Adaptive Instructional Management System and refers to a major dissemination and use of the project.

# ABSTRACT

A computer-based system model for the monitoring and management of the instructional process was conceived, developed and refined at New York Institute of Technology through the techniques of systems analysis. It was applied and tested with respect to three courses of study (Physics, Mathematics and Introduction to Data Processing), at New York Institute of Technology, to a Physics course at the United States Naval Academy at Annapolis, Maryland, and on varied instructional programs of other institutions for instruction given within their home sites.

Each course was directed toward a defined student population; each employed a unique selection of instructional media; and each was designed to explore a distinct facet of the computer program's capabilities.

Specific behavioral objectives for each of the courses were created, coded and cross-referenced to all of the instructional and testing materials. As the students progressed, with varying rates and differing strategies through the instructional materials, they and those concerned with management of the course, received the information necessary to individualize the programs for each student.

Responses to both the instructional and testing programs were recorded on a variety of devices to allow for the collection of data reflecting every decision made by the student. The statistical analyses of these data were presented in formats which informed the student ot his progress, and specified remedial prescriptions where required. Individual and group statistics were generated for analysis by the professionals concerned with administration or design, and formed the basis for subsequent revisions by the strategies leading to course optimization.

This system has been operative both on the NYIT campuses and other school environments and has been demonstrated to a cross-section of the educational community.

## A. CONCLUSIONS

The original objectives desired in this research project were met. The developed computer based model system offers a system for individualizing and optimizing learning through computer management of the educational process and has pertinence well beyond the limits of Mathematics, Physics, and Computer courses upon which it was tested. The system also has applicability to a wide range of grade levels and a broad spectrum of subject areas. It should be understood that *it was the primary purpose of this research to study the viability of such a management system;* the development of the specific course

content and format were secondary, although the products thereof were substantial and capable of replication in other learning situations. This goal was achieved.

Major large scale use of the system in the future seems assured in both local school districts and within New York State at the least.

The project aimed at providing better monitoring capabilities over the learning systems that were in operation at NYIT and other cooperating school systems. The curriculum designs developed under the program were validated and optimized at the Institute and then tested in local participating schools, using the same management system in the preparation and refinement of course content, media, etc., at the local levels as proven out in the Institute. Also, the system was tested in a multi-media course design for Physics for the U.S. Naval Academy, Annapolis, Maryland.

The program resulted in better organized accurate hard data relating to the materials, equipment and systems that will be used in actual instructional operations. It provided for testing and assessing the various instructional methodologies employed, as well as verifying the content and the performance of the software and strategies used to obtain any particular learning point. It provided a frame of reference and assessment data relating to a set of strategies, a set of instructional materials, and a set of hardware suited to the subject areas under consideration, and relevant to the needs of particular students undergoing these learning experiences.

The professional teams concerned with this program have integrated into the instructional process an extensive range of media, selected from among all the texts, films, television tapes, audio tapes, transparencies, slides and filmstrips, workbooks, the behavioral games available today, and any other materials that are necessary to attain the educational aims of the courses, and to design new aids and devices when needed.

Computer Assisted Instruction as a technique received due attention. CAI was used as a prime resource in the computer sciences program. The intent, to provide experience in the use of CAI (and to evaluate its effectiveness) for the teachers and students in the Institute and in the cooperating secondary school system, was accomplished. In this phase of the research, the management system showed it could isolate from a list of previously determined learner characteristics those which are related to success and failure for a particular student in a given segment and predict his performance on succeeding segments, thus providing the information necessary for a proper judgment by the teacher or learner relative to choice of media and materials.

The computer-based analysis and evaluation of the results of the use of this range of relevant material enabled a teacher or learner to move from the old pattern of selecting from a variety of uncoordinated materials to a coordinated system, integrated, capable of easy updating and based upon a store of specific experience about particular learning materials, equipment and software demonstrated pertinent to the subject matter areas treated experimentally in this program.

In terms of improving the learning process, as demonstrated by improved achievement of the students involved in the courses covered by the experimental program, significant measurable results were obtained.

# 1

# THE OVERALL SYSTEM

*An overview of the entire system; the approach, objectives, and procedures.*

# THE OVERALL SYSTEM

## Table of Contents

Page

I. Discussion of Approach: A Governing Philosophy ........ 1

II. Scope ........ 3

III. Specific Objectives of the Adaptive Instructional Management System ........ 4

IV. Procedures ........ 5

## I. DISCUSSION OF APPROACH: A GOVERNING PHILOSOPHY

The ultimate aspiration in the development of the AIMS System was to achieve a Generalized Educational Management System (GEM), designed to encompass the totality of the educational environment in which it operates. GEM is based on an advanced data file access/retrieval system, with innate adaptive feedback characteristics. Sequential Access File Entry System (SAFES) provides a data-base capable of supporting the operation of virtually any kind of process model. A generalized simulator, which effectively becomes a unique computer language, can be used to develop models of a wide range of educational environments, emulating discrete aspects of the education sphere.

The basic structure of a Generalized Educational Decision Structure (GEDS) is created, and specified, as educational process information is fed into the system. Upon specification, the simulator reduces to a model of an aspect of the educational environment. Examples of such models, which can be generated by the simulator, are:

- Community Subsystem...providing output of Earning Potential, Job Opportunities, Occupational Acceptance Levels and Attitude Values.

- Instructional Process Subsystem...resulting in Change in Attrition, Change in the Number of graduates, and Change in Achievement output information.

- Cost Subsystem...giving Total Program Effectiveness, Improved Resources, and a Computed Cost Listing as end products.

- Instructional Process Input System...For the pupil population in the program, outputs Change in Achievement, Change in Attitude (index of learning difficulty) to School and Cost Effective submodels.

    - AIMS.....Instructional Management

    - ULTRA....Educational Guidance

    - IMIS.....Educational Administration and Library Management

    - PROMIS...Educational Planning and Evaluation

The Adaptive Instructional Management System (AIMS) has been designed to monitor, score, and evaluate individual students, groups of students, and curricular content in a course environment designed for educational management. Design philosophy included providing course administrators with a meaningful analysis, and constructive assessment of student or group performance within the environment of a course created for computer management. Since the system requires a minimum of "installation tailoring," AIMS is capable of servicing most user requirements once adapted to the course environment. Through its modular construction, it is possible to incorporate other student input techniques for time-shared and teleprocessed implementation.

AIMS Version III was generated to be as versatile as possible, without prohibitive INPUT/OUTPUT requirements. To insure versatility and compatibility, it was designed around IBM System/360, and was generated with the Model 30/Release 20 IBM Disk Operating System (DOS).

The overall design concepts governing the development of AIMS constitute:

- Machine independence to the maximum possible extent; can be adapted to a wide variety of machine configurations.
- Creating, maintaining and accessing a large data-base, relevant to student curricular, pedagogical, and administrative aspects of a given scholastic environment.
- Creating, maintaining, and accessing sub-files containing meta-data.
- Providing printed analyses of past, current, and future student progress throughout the scholastic environment.
- Generating an adaptive feedback loop through which the system can modify its multiple-model simulator to reflect current conditions within its sub-files.

The system, through the media of feedback and analysis, incorporates the necessary procedures for updating and optimizing the general level of instruction and testing.

Extending into the Behavioral Psychology environment enables AIMS to produce a matrix showing the relationship between Terminal Objectives and Enabling Objectives learning or skill category, media type, and each individual question. The inclusion of a validation capability has made AIMS the ideal vehicle for experimental curriculum analysis.

## II. SCOPE

The original principal objective desired in this research project was to develop a computer-based model system offering a system for individualizing and optimizing learning through computer management of the educational process. It was to have pertinence well beyond the limits of the courses upon which it was tested. The system also was to have applicability to a wide range of grade levels and a broad spectrum of subject areas. It should be understood that *it was the primary purpose of this research to study the viability of such a management system*; the development of the specific course content and formats were secondary, although the products thereof were substantial and capable of replication in other learning situations.

A computer-based system model for monitoring the management of the instructional process was conceived, developed and refined at New York Institute of Technology through the techniques of systems analysis. It was applied and tested with respect to three courses of study: Physics, Mathematics and Introduction to Data Processing, at New York Institute of Technology, to a Physics course at the United States Naval Academy, Annapolis, Maryland, and on varied instructional programs of other institutions for instruction given within their home sites.

Each course was directed toward a defined student population; each employed a unique selection of instructional media; and each was designed to explore a distinct facet of the computer program's capabilities.

Specific behavioral objectives for each of the courses were created, coded and cross-referenced to all of the instructional and testing materials. As the students progressed, with varying rates and differing strategies through the instructional materials, they and those concerned with management of the course, received the information necessary to individualize the programs for each student.

Responses to both the instructional and testing programs were recorded on a variety of devices to allow for the collection of data reflecting every decision made by the student. The statistical analyses of these data were presented in formats which informed the student of his progress, and specified remedial prescriptions where required. Individual and group statistics were generated for analysis by the professionals concerned with administration or design, and formed the basis for subsequent revisions by the strategies leading to course optimization.

Although the present system is directed to management at the level of school and course work, it may be viewed as a component of a projected Generalized Educational Management System (see Unit 2) in which the total educational experience is simulated, and optimal instruction is provided on the basis of background variables and recent past performance

## III. SPECIFIC OBJECTIVES OF THE ADAPTIVE INSTRUCTIONAL MANAGEMENT SYSTEM

1. To organize, develop and refine by a systems engineering approach a model computer-based system for the management of the instructional process, operationally and economically feasible, and capable of:

    a. replication at alternate educational levels;

    b. self-improvement through continuous rapid feedback of hard data, recorded, interpreted, analyzed and presented for decision by computer;

    c. individualizing and improving the learning of each student in a heterogeneous population in specified curriculums and subject sequences;

    d. managing, toward optimization, instructional programs having applicability to general and occupational education;

    e. establishing the parameters for guidance, counselling and screening of students in such programs;

    f. providing definition of goals, course content, prescriptions and instructional strategies related to the selected curriculum areas.

2. To implement, test, revise, restructure and optimize the system in selected courses (Mathematics, Physics, Computer Sciences), in a selected environment at New York Institute of Technology and in a multimedia physics course at the U. S. Naval Academy, Annapolis, Maryland.

3. To demonstrate replicability and viability of the system for one course within at least one other typical environment such as the Nassau County Secondary School system.

4. Concurrently, to train those members of the community operationally involved with the educational process at both the secondary and collegiate levels, so as to ensure effective operation of the system.

5. To disseminate to interested segments of the educational and social communities the findings and conclusions of this study.

## IV. PROCEDURES

1. In order to accomplish the objectives of this proposal, an "action research" program was prepared which when implemented, achieved specific goals set forth above.

    a. This program allowed for the development, test refinement of the management system, application of the system to a specific environment in the subject matter areas, and the repetition of the system in another context so as to demonstrate replicability.

    b. Training of appropriate members of the educational community who were involved operationally in this effort, and the dissemination of the findings of this study to the educational community at large were also provided for.

    c. Procedurally, the "action research" program encompassed several interrelated categories of activities.

    d. An initial, and continuing, category of activities covered the design and development of the computer-based management system itself, through which the assessment, revision, restructure optimization and validation of the instructional system were accomplished. Since the system was self-generating and self-correcting, these activities involved empirical implementation and observation under actual living school conditions and testing, modification and retesting in such a viable situation.

    e. Therefore, a concurrent category of activities addressed itself to the development of subject matter courses, with appropriate support material and their testing, revision, restructure towards optimization and validation. These latter activities were governed within the instructional management capacities of the developed system. The methods of attack, the step-by-step procedures whereby the courses were behaviorally defined, structured, refined and validated, evolved directly from the system design and were controlled and directed by the computer-based management system.

f. A third category covered the tasks involved in the replication of the management system and the teaching of the sample courses in selected other environment; the training of that personnel concerned at the Institute and, at the cooperating school systems.

g. Finally, there was the dissemination of the findings of the study for broader application throughout the educational community.

2. These major categories of activites went, to a certain extent, concurrently.

   a. The course development activity, particularly as it reached the implementation and assessment stage, was dependent upon the management system, with its immediate feedback and analysis. The management system, conversely, required the course development activity as its "test bed" upon which it based its own growth and shape. Final validation of both the course and the management system depended upon the experiences of the replication experiment.

   b. During the study, New York Institute of Technology utilized as course areas:

      (1) Data processing

      (2) Mathematics

      (3) Physics

   These subject matter areas were chosen because they formed entities which were relevant to the philosophies expressed in an appropriate Office of Education position paper relating to career education; they fell within an area of national need existing at the time of the study. The Institute possessed demonstrated expertise in these subjects; and, they had relevance to secondary educational levels. Prepared as was intended, they could serve either as remedial or preparatory materials for a more advanced program or a step-by-step outline of the procedure followed is set forth below. Also, the system was complemented at the U. S. Naval Academy, Annapolis, Maryland.

3. The total program was scheduled over a period of three years, with Phases I, II, and III coinciding, each with a consecutive period of approximately 12 months. The three major procedures follow:

   a. Development of the System Design for the computer managed system. This system was designed at New York Institute of Technology by the in-house staff of the Institute's Advanced Systems Laboratory. The management system encompassed subsystems. Capacities included among the major educational components were:

      (1) *Goals* (curriculum objectives expressed in behavioral terms delineating precisely the substance of the educational program, the skills and knowledge to be learned.)

      (2) *Students* (as inputs to the system, with profile structure academic levels, proficiency attainment and all other relevant data relating to their selection and subsequent education.)

      (3) *Curriculum, course and instructional content* (software and programs designed to accomplish specifications of (1) above.

      (4) *Instructional strategies* - the combination of methods, media and organization required to conduct the learning program.

      (5) *Assessment, tests and procedures.*

      (6) *Instructional decision making and prescriptions.*

      (7) *Feedback and restructure mechanisms.*

(8) *Organization and Facilities* (personnel, facilities, faculty and equipment required to support other subsystems.)

4. Implementation of the system at New York Institute of Technology (the procedure outlined below was applicable to all of the subject matter areas incorporated in this program).

    a. Pertinent input data appropriate to the subject matter areas were accumulated and the teaching-learning environment involved, to determine as much as was practicable about: the students, the existing programs, instructional strategies and media employed in the subject matter areas, past performance records, etc. During this process of data accumulation, the faculty were directly involved.

    b. The specific steps included:

        (1) Primary faculty orientation.

        (2) Examination of student qualifications.

            (a) Prerequisite knowledge base - scores as available in basic knowledge areas - recency of learning experiences of prerequisite knowledge.

        (3) Examination of prior performances of student in the major subject area categories.

            (a) Analysis of achievement test scores in each defined area.

        (4) Discussion with faculty to:

            (a) Define *level* of comprehension ultimately to be achieved by the student upon successful completion of the course, and in each major subject matter area category.

            (b) Define existing overall course objectives.

(c) Identification of current Behavioral Objectives, if any.

(d) Identification of existing remedial prescriptions.

(e) Review of existing instructional strategies, order of presentation (sequencing), media and teaching aids employed.

(f) Review of existing tests and assessment.

(g) Review of existing achievement criteria.

c. All input data thus accumulated were analyzed and, giving due respect to faculty desires, suggested changes and additions to existing course objectives were defined, particularly by determining areas in which improved quality of student performance (or reduction of time while maintaining acceptable quality) were clearly indicated.

d. Modifications and additions to existing course content were developed, including new overall course objectives.

e. Behavioral Objectives were prepared. When all the above-detailed steps necessary for the development of course content, course objectives, planned remedial areas, etc., (the "syllabus") had been accomplished, the researchers redefined the detailed Behavioral Objectives necessary to fulfill the syllabus, taking into account:

(1) Level of instruction desired.

(2) Total time allowed for the overall course.

(3) Specification of "enrichment" or optional Behavioral Objectives.

(4) The requirement that the sum of all the Behavioral Objectives in each subject matter area covers the topic to the level desired by the faculty.

f. The courses were sequenced, considering such factors as:

   (1) Existing student knowledge and skills.

   (2) Interaction of subject matter content.

   (3) Sequencing based on historical patterns (population stereotypes).

   (4) Instructor preferences and bias.

   (5) Difficulty of material.

   (6) Availability of media.

g. The proficiency measures were developed to:

   (1) Expose areas for remedial branching.

   (2) Establish the extent to which Behavioral Objectives were achieved.

   (3) Permit assessment of class achievement and establishment of class standing.

h. Media of instruction were selected, resources identified and instructional strategies determined, based upon the following criteria:

   (1) Success (or failure) of existing resources and strategies as used at New York Institute of Technology and at similar institutions.

   (2) Ease of preparation and relative cost.

   (3) Ease of modification.

   (4) Applicability to evaluation or scoring.

   (5) Uniformity with which techniques can be applied.

(6) Ease of transition to remedial branches.

(7) Consistency of media, as applicable to a sequence of learning units.

(8) Ease of transition from one media to another.

(9) Naturalness (for example, if the learning problem involved differentiation of sounds, the use of audio tapes was indicated).

(10) Need to sustain interest.

The computer management aspects of this program presupposed test and assessment of all elements of the instructional process, and revision, restructure, retest and further restructure, on a continuing basis. This methodology dictated that the instructional materials, particularly in their early generation, be as inexpensive and suitable for modification as was consistent with the minimum effectiveness required for evaluation.

Critical to the success of the computer management was the Adaptive Instructional Management Subsystem developed as part of the management system. In essence, the Adaptive Instructional System was a self-adaptive system embodying prediction, evaluation, record keeping, and feedback mechanisms. The objective of the system was to provide a logical basis for simultaneously improving curriculum and optimizing instructional decision processes for increasing individual student performance.

Perhaps the single most important design characteristic of the proposed subsystem was the continual improvement property. This allowed for continual testing of new ideas in course presentation and content. In addition, the system continually improved its prediction capabilities relating to individual student instructional strategies.

i. A tryout of the materials was closely monitored by subject matter specialists and behavioral psychologists. Data was accumulated for the revision:

   (1) All test scores

   (2) Student attitudes and preferences

   (3) Time in media

   (4) Student questions

j. The revision process was effected using a systems analysis approach.

   (1) All performance measures were compiled according to associated terminal objectives.

   (2) All items were validated.

   (3) Lists were prepared which identify those terminal objectives with poor performance associated with each major measure.

   (4) The listed correlations and compiled data are examined and various revision actions taken. These include classification of objectives, amplification of enabling objectives, and supporting material; adding information panels, test assignments, time available for study, audiovisual materials, and alternate individualized routes.

# 2

# SYSTEMS APPLICATION IN HIGHER EDUCATION

*A systems approach to computer managed instruction as a vehicle for accountability and evaluation in education; the present project is viewed as a component in this broad plan.*

# SYSTEMS APPLICATION IN HIGHER EDUCATION†

## Table of Contents

I. OVERVIEW .................................................. 1

II. THE NEED FOR SYSTEMS RELATED INFORMATION ........... 1

- A. Rationale ........................................ 1
- B. Systems Related Information Yields - The Accountability Process .................... 2
- C. Characteristics of the Accountability Design ........................................ 4

III. THE OVERALL DESIGN MODEL AND HOW IT OPERATES ........................................... 5

- A. The Generalized Educational Management System ........................................ 5
- B. System Objectives ............................ 8
- C. The Sequential Access File Entry Subsystem ................................... 9
- D. The Generalized Simulator ..................... 9
- E. The Automated Instructional Management System ........................................10
- F. Additional Evaluative System Characteristics ..................................16
- G. The Guidance Model ...........................18
- H. The Institutional Management Information System ................................23
- I. The Program Management Information System ........................................23

IV. CONCLUSION ..........................................26

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## SYSTEMS APPLICATION IN HIGHER EDUCATION

### Table of Figures

FIGURE 1A .................................. 6
FIGURE 1B .................................. 6
FIGURE 2 ................................... 7
FIGURE 3 ................................... 7
FIGURE 4 ..................................17
FIGURE 5 ..................................19
FIGURE 6 ..................................20
FIGURE 7 ..................................21
FIGURE 8 ..................................21
FIGURE 9 ..................................24
FIGURE 10 .................................24
FIGURE 11 .................................25

A pressing need for educational accountability and evaluation is now widely recognized. Investigators at the New York Institute of Technology have developed a computer-based instructional management system which encompasses these critical functions; the philosophy and application of this total accountability system is discussed here in a broad context.

## I. OVERVIEW

The greatest future impact of the computer upon higher educational patterns may exist in its capacity to manage total systems. Analyzing well defined systems, the computer can guide the learners, professionals, and agencies involved in higher education to methods maximized to attain their goals. Sophisticated system-related information processing should result in more efficient decision-making processes, more relevant instructional management tools, and increasingly effective manpower-solving procedures. Such potentials can be used to affect present-day higher education, principally by providing guidance, accountability and evaluation measures for the various constituencies concerned with the education process. Once operative, useful information becomes available as to what works or what does not--where gains occur and where they do not. The criteria must be such as to be useful and acceptable to the users of the system--not those imposed "a priori" by systems designers.

## II. THE NEED FOR SYSTEMS RELATED INFORMATION

### A. RATIONALE

The pressures on the total educational system are intense. The ever increasing number of learners demands new arrangement, additional services and teacher training. The question of effectiveness of the various programs is paramount.

Evidences of major stress are legion. Elementary schools are plagued with less than satisfactory levels of achievement for the heterogeneous groups of pupils they serve. Schools are faced with the problem of adding to their already overburdened operations a vastly expanded post high school education as the minimal career requisite of an increasing segment of the population.

There is a ubiquitous lack of relevant occupational training, misdirected career and curriculum guidance, and the arbitrary academic behavioral objectives fixed by tradition rather than realistic needs. Inflexible and inappropriate instructional pacing is often dictated by administrative convenience rather than the actualities of student performance. Frequently little, if any, use is made of successful innovative educational practices, models, and methodologies--due to a lack of information and professional know-how. The usual educational establishment is bereft of sufficiently rapid feedback on which to base corrections for deficiencies on the basis of any combination of the following: inadequacy of environment, resources, and methodologies; mismatch of teacher and learner; insufficient prerequisites and preparation; poor learner attitudes; or the innumerable other tangible and intangible factors which influence the effectiveness of the learning process. It is of little surprise that talent and funds are eroded by inefficiency. Educational planners hope the sophisticated capabilities of modern technology can reverse the pattern.

## B. SYSTEMS RELATED INFORMATION YIELDS - THE ACCOUNTABILITY PROCESS

The present national commitment to better educational opportunities for all young Americans is having an unprecedented impact on the educational establishment. The urgency of the goal is viewed as a testimonial to the scope of our failure.

Already the proposals are beginning to mount: more remediation, more tutorials, more in-service training programs, more advanced technology, more demonstration projects--in short, more money for more of the same things we have been doing for the past ten years. Obviously, some very important questions will have to be answered before we can in good conscience buy our way out of another educational crisis.

We are not prepared to characterize all our efforts in education to date as total failure. Our problem is that we do not know where or whether we have failed or not. We have poured millions of dollars into hundreds of programs and collected mountains of unusable data. A larger investment will only generate more undecipherable data because we do not have the capacity to relate the data from one system to data from another among the myriad of systems tests administered in our schools.

A massive, computer-based information system effort to identify those means which provide the most usable information and to develop a national evaluation system that will best relate the best procedures is one way out of the current crisis. Urgent needs in the areas of health and housing and poverty do not afford us the luxury of across-the-board random experimentation. Sound principles of systems utilization dictate that we stop bending all our efforts to assembling data and that we begin the task of genuine assessment.

A workable educational accountability and evaluation system must provide information for each one of its prospective users; an individual must be supplied with evaluation data that is explicitly relevant to the particular facet of the educational endeavor he wishes to examine. Clearly, not everyone perceives the educational enterprise from the same perspective. In essence, an accountability information system which is not flexible enough to supply a wealth of information, to different groups, in formats they will accept, is simply not usable.

A malleable system design, a readily accessible data base, and information for evaluation of education on any dimension relevant to the users of a specific system are essential for complex explorations of the educational process. These requirements necessitate, then, that the information system must be broad-based, be free of the attitudinal and value biases of its designers, and yet be sufficiently flexible to be responsive to the attitudinal and value biases of its users.

Simple information, such as a comparison of individual types of student achievement against a national norm, has been accessible for some time. Evolving technologies, however, have facilitated the growth of information systems capable of more sophisticated evaluations. With such a system, complex new endeavors are possible; one could, for example, look at amalgamations of variables which previously were not subject to direct evaluation due to confounding effects. Now one can begin to record effects of environmental and strategic variables, in combination, on the people being served by a given educational enterprise. The results of such a systematic data analysis do not imply any superlative or mandatory pedagogical procedure, but they do provide guidelines on the effects of specified combinations of variables on performance in the educative process.

An information system such as that described above can serve to establish evaluative baselines that are currently lacking in the educational profession. Evaluation is impossible without such guides; an information system can supply the criteria for evaluators seeking to explore educational processes.

An educational program is about to be evaluated. What is to be the criterion of judgment? Will it be the length of learning time? The cost per pupil? In times of war, rapid military training in some areas are critical. Then, assuming equivalencies of learning and retention, it is time as opposed to money that assumes an evaluative priority. Similarly, the ratio of pupil-expended time to pupil successes to dollars spent might be the major criterion for evaluation of an educational program (perhaps the attrition rate is high because the length of time required for completion of the program is too lengthy to meet the pressing needs of an active student). Again, in any specific case, what is to be considered too much time or too much money? At present, these judgments are often based on the intuitive perceptions of an evaluator. An information system, however, could provide a baseline. The baselines generated by an information system will not serve as overnight cures to educational ills, but will supply clues to what can be considered adequate performance in specified educational situations.

If it is asserted that teachers, as professionals, be held accountable for an excess of "mortality cases" within the schools, it becomes necessary to stipulate the baselines for their guidance. What can the average teacher accomplish with a class of specified number, age, sex, racial, religious, and socio-economic characteristics found within a given environment? From total operating systems, the information system can provide the knowledge of baselines structured under specific conditions that will facilitate evaluation and accountability in the teaching profession, and in other educationally related occupations.

## C. CHARACTERISTICS OF THE ACCOUNTABILITY DESIGN

Two continuing broad phases must characterize the systems evolved. The first is to develop an educational format which is appropriate to the needs of a relatively heterogeneous student body--and to do this through an instructional management program, employing resources and guidance growing out of modern educational methodologies. The second phase involves implementation of the model, making it responsible to the needs of users.

Clearly, the aims and activities are ambitious and difficult to obtain. Hope of success rests largely on the belief that by instructional management through systems analysis, an operational program which realizes significantly greater efficiencies than currently attained is possible. As soon as such a model can truly be made applicable to a much wider range of students (the regular, the professional in need of upgrading or updating, the advanced, the geriatric, the pre-school, etc.) then its significance for all education would increase materially. Further, if the system proves inherently self-improving, and is flexible enough to include interaction with environments not always directly considered as influencing education (industry, labor, community, etc.), the new dimensions in education and training may be anticipated.

The model envisions providing several desirable outcomes:

1. A generalized self-improving model for instructional management applicable to a heterogeneous population in diverse environments.

2. A test bed for the model applicable to high school and post high school populations, including academically and economically disadvantaged youngsters in occupationally related programs.

3. A sharper focus on unanticipated needs for 1. and 2. above, resulting from empirical feedback following implementation.

4. A design model which can be a basis for a total system applicable to the general needs of education

5. A design model which can test alternative routes of higher education, in consortiums with public and private sectors not normally fully utilized, to advance efficiency and reduce costs of higher education.

6. A design model which can serve as a basis for the development of accountability and evaluation guidelines against which there may be established higher standards of efficiency for given dollar expenditures.

7. Provide guidelines for performance contracting and independent educational accomplishment audit.

Accountability in a system presupposes both obvious and subtle components. It demands that both the system interactions and its component operations be made available for scrutiny, so that verification of outcomes is possible. It implies that the outcomes be related to the objectives to determine the extent of achievement. It suggests that dynamic forces be operated to correct deficiencies and improve the system. It insists that its system interact with the environment because even in minimal interaction the environment includes the observer to whom the accounting is provided.

## III. THE OVERALL DESIGN MODEL AND HOW IT OPERATES

### A. THE GENERALIZED EDUCATIONAL MANAGEMENT SYSTEM

A system plan which incorporates the power and flexibility required for accountability and which is applicable to a wide range of educational situations will be described briefly. The designs referred to are those evolved by the Advanced Systems Laboratory of the New York Institute of Technology, Old Westbury, Long Island, as part of its continuing research into the structure of relevant educational accountability and evaluation measures. To this end, a major effort of the laboratory's cadre is concerned with the development of a Generalized Educational Management System (GEMS). Conceptually, GEMS is based on three components capacities: (1) an advanced data file access/retrieval file handler capability; (2) a simulator availability; and, (3) an adaptive feedback mechanism.

The total system represents the synthesis of a variety of subsystems which have been conceptualized, developed, and to varying degrees implemented at the Institute and elsewhere. As outlined in Figure I(a), (b), GEMS includes the following subsystems.

Figure 1A

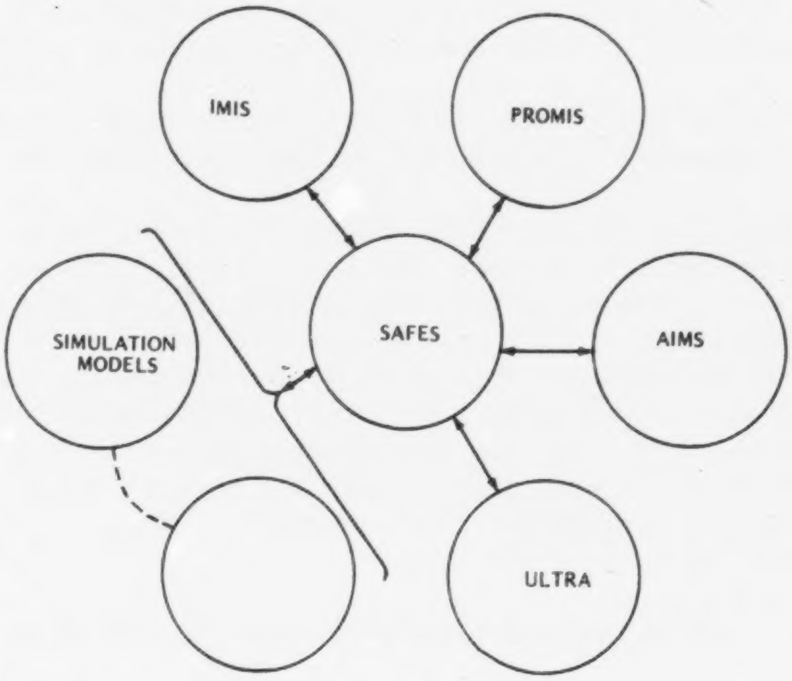

IMIS
PROMIS
SIMULATION MODELS
SAFES
AIMS
ULTRA

Figure 1B

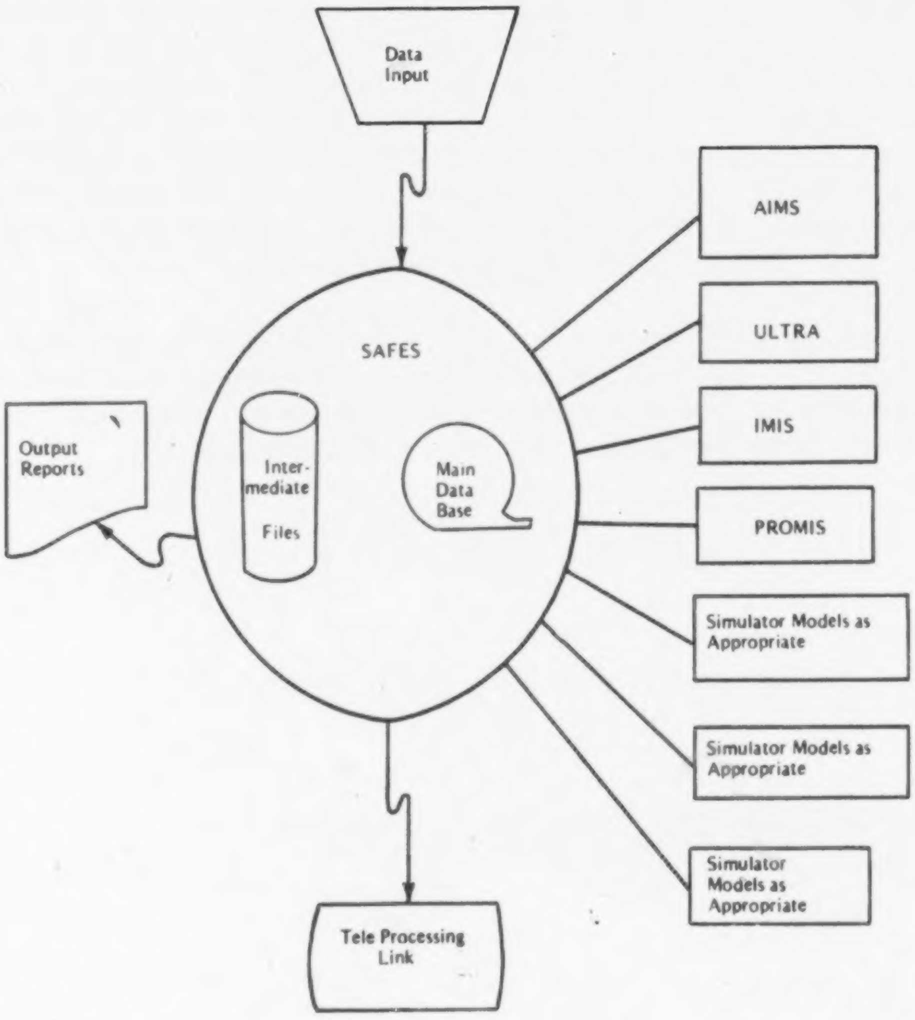

Data Input
AIMS
SAFES
ULTRA
Output Reports
Inter-mediate Files
Main Data Base
IMIS
PROMIS
Simulator Models as Appropriate
Simulator Models as Appropriate
Simulator Models as Appropriate
Tele Processing Link

Figure 2

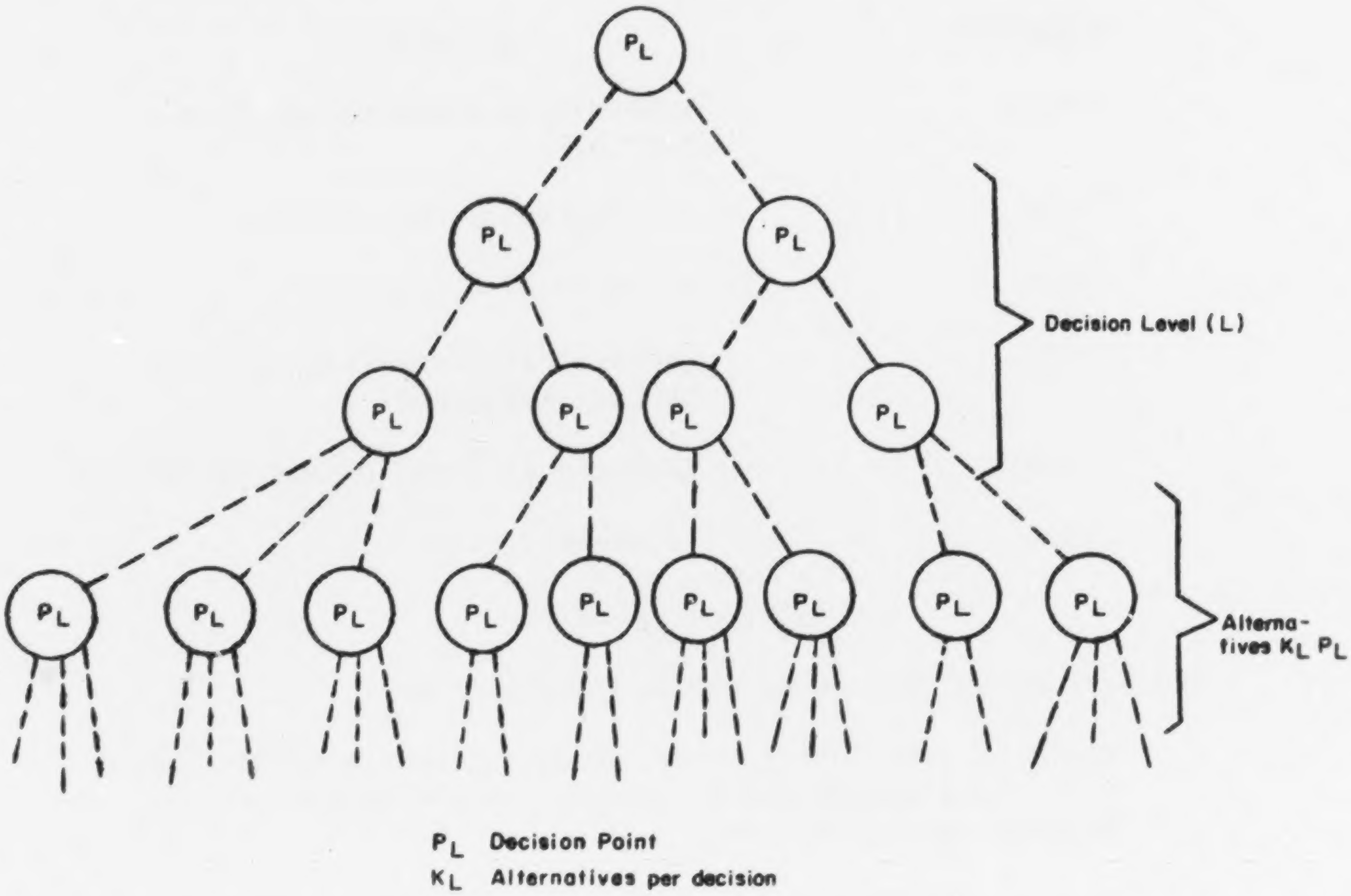
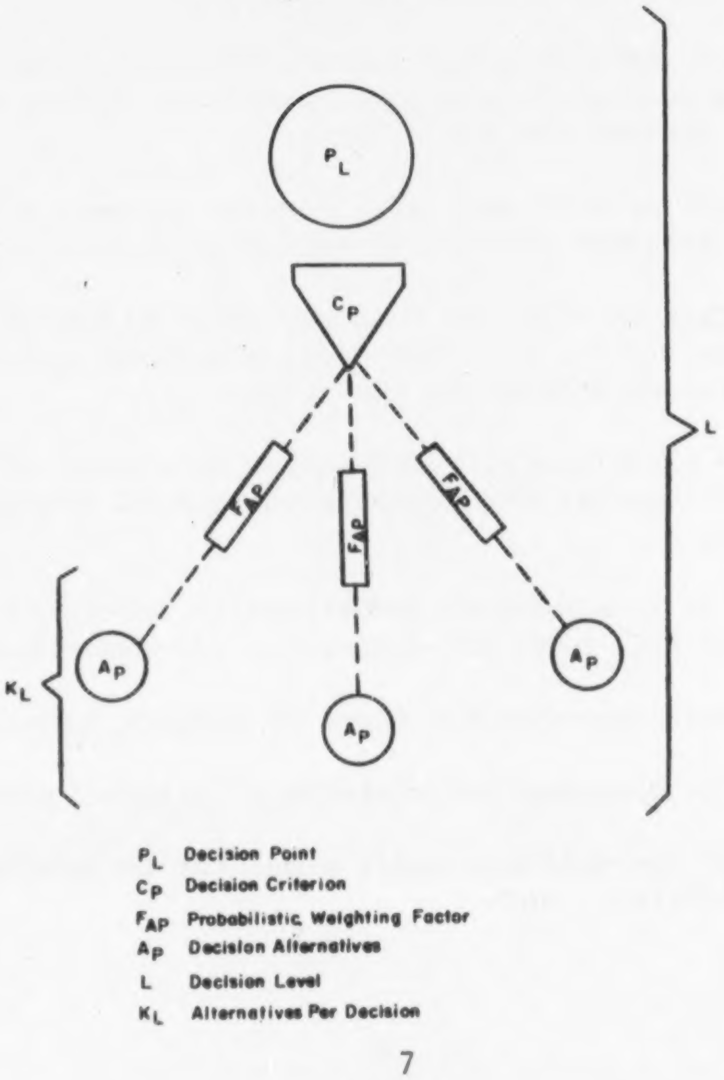

$P_L$
Decision Level (L)
Alternatives $K_L$ $P_L$
$P_L$ Decision Point
$K_L$ Alternatives per decision

Figure 3


$P_L$
$C_P$
$F_{AP}$
$A_P$
L
$K_L$
$P_L$ Decision Point
$C_P$ Decision Criterion
$F_{AP}$ Probabilistic Weighting Factor
$A_P$ Decision Alternatives
L Decision Level
$K_L$ Alternatives Per Decision

| SUBSYSTEM | APPLICATION |
|---|---|
| SAFES | Information Handling and Data Retrieval |
| AIMS | Instructional Management |
| ULTRA | Educational Guidance |
| IMIS | Educational Administration and Library Management |
| PROMIS | Educational Planning and Evaluation |
| ETC | ...other models |

## B. SYSTEM OBJECTIVES

The systems objectives of GEM are designed to:

1. Yield machine independence to the maximum possible extent (i.e., the system can be adapted to a wide variety of machine configurations);
2. Create, maintain and access a large data-base relevant to student curricular, pedogogical, and administrative aspects of a given scholastic environment;
3. Create, maintain, and access sub-files containing meta-data (data processed from main data-base, having high information content and low noise);
4. Provide printed analysis of past, current and future student progress throughout the scholastic environment;
5. Generate an adaptive feedback loop through which the system can modify its multiple-model simulator to reflect current conditions within its sub-files;
6. Allow experimental modification of system parameters so as to forecast the probable outcome of contingent decisions;
7. Provide a mechanism for externally initiated investigation of the data-bank for evaluation and experimentation;
8. Generate linkages for input of modules into system;
9. Develop mathematical skeleton of simulation mechanism;
10. Employ one multiple-model simulator to generate pertinent information; and

11. Crystallize and incorporate foundations for time-shared and teleprocessed implementation.

## C. THE SEQUENTIAL ACCESS FILE ENTRY SUBSYSTEM

The file handler requisite is embodied in the Sequential Access File Entry Subsystem (SAFES). It provides an open-end data storage and retrieval medium with multiple levels of indexing. This subsystem is self-allocating; i.e., upon being provided with information relative to the nature of the input data, it will allocate the appropriate file spaces and indices. SAFES will create and maintain both direct access (disk) and sequential access (tape) files in any number and of any length as well as provide for all data transmission within the system. SAFES provides the communications and data environment in which each of the subsystems operates. Any number of simulation models can be driven by SAFES from which they are supplied with raw data as well as reduced data.[1] When functioning in a large-scale, time-shared, tele-processing environment SAFES will create and maintain files in any variety of storage media; monitor the usage of any file or sub-file; reorganize any file or sub-file to maintain maximum access efficiency; and, make optimal use of physical storage media.

## D. THE GENERALIZED SIMULATOR

A generalized simulator, which effectively becomes a unique computer language, is used to develop models of a wide range of educational environments. The basic structure of a Generalized Educational Decision Simulator (GEDS) is presented in the accompanying diagrams (Figures 2 and 3). This structure is created and specified as educational process information is fed into the system. Upon specification, the simulator reduces to a model of an aspect of the educational environment.

Fundamentally, the simulator is a variable decision structure, the lattice of which outlines the components (rational and alternative) of decision processes.

In keeping with the principle of modularity and flexibility, the decision structure is a tree configuration of x levels and y alternatives per decision. The criteria for each decision evolves from specific constraints of selected student history or performance parameters. These constraints may be absolute; i.e., numeric constants or ranges, algorithmic, or based on statistical probability levels relative to an analysis of class data. Such a device is comparatively rigid in that it cannot be easily modified to reflect changes in student data or course strategy. This is overcome by incorporating into each decision process a probabilistic weighting factor developed either intrinsically or by a student data analysis. As a result, the likelihood of a single path being chosen in a given decision process can be increased or decreased without reprogramming.

From the above description, it is obvious that the simulator is highly flexible, and capable of being adapted to a changing educational environment quite easily.

The feedback mechanism provides the device for accomplishing this adaptation, using mathematical pattern recognition as its basis. In essence the process consists of analyzing the student data bank with the object of detecting and classifying patterns of academic behavior. Once these patterns are known, categories are established by specifying constant relationship between student parameters. An individual student is then evaluated by comparison with each category until the most appropriate category is selected and a metric conformity is determined. Such a device, which becomes more certain as the number of categories and the population in each increases, is used to drive a reporting subsystem and to manipulate the weighting factors in the simulator. Hence, a truly modifiable system capable of improving with experience is generated. Due to the open-end nature of the file and the ability of the system to access all available data, the experience of time is ever cumulative and can be duplicated at will.

## E. THE AUTOMATED INSTRUCTIONAL MANAGEMENT SYSTEM

In its simplest and most elementary form the systems analysis approach at New York Institute of Technology which constituted the initial phase of structure of the Automated Instructional Management System (AIMS) consisted of carefully specifying three sets of conditions:

1. Desired outcomes or objectives of the system;
2. A detailed audit of the characteristics of the system, the system inputs, before they are operated upon or affected by the system;
3. An explicit description of relevant means-ends relationships and methods for assessing efficiency and/or efficacy, i.e., effective ways in which systems resources may be organized to provide pathways to desired objectives.

Then, the appropriate phases relating to instructional management required development of specifications and/or codifications of:

a. Goals (curriculum objectives expressed in behavioral terms delineating precisely the substance of the educational program, the skills and knowledge to be learned);

b. Students (as inputs to the system, with profile structure, academic levels, proficiency attainment and all other relevant data relating to the selection and subsequent education);

c. Curriculum, course and instructional content (software and programs designed to accomplish specifications of (a) above);

d. Instructional strategies--combination of methods, media and organization required to conduct the learning program;

e. Assessment, tests and procedures for evaluation;

f. Instructional decision-making and prescriptions;

g. Feedback and restructure mechanisms;

h. Organization and facilities (personnel, facilities, faculty and equipment required to support other subsystems).

The objectives of the Automated Instructional Management Subsystem are to provide self-adapting mechanisms which will aid in the evaluation of student progress; provide for prescriptive measures for remedial or enrichment material; allow empirical validation and optimization of course organization, content, strategies, and media; provide a record-keeping and communication function for the pupil, the teacher and the school; and, provide continual feedback to improve functional effectiveness of the system.

In addition to the linkages to the data base, including all file maintenance functions (SAFES), AIMS consists of a report generation subsystem coupled to a heuristic simulator with an adaptive feedback element. The goal for this subsystem is to provide for the use of the pedogogue a wide range of information processing tools for the analysis and evaluation of student progress and curriculum.

Coupled to the file handling capabilities of SAFES, AIMS includes supporting input-output options which allow it to:

1. Perform and report item analyses of student test questions;

2. Receive data on student performance and background history as well as course structure;

3. Provide for multiple formats for input data; i.e., without reprogramming, the system can be adapted to a wide range of input formats;

4. Produce any number of selected output reports which tabulate data relative to individual student performance profiles, and course validation;

5. Permit the selection of students from the main database whose parameters conform to certain specified

constraints and perform any of 25 statistical operations on selected parameters of the selected students.

It is again emphasized that the design characteristics of SAFES permit it to be used as a general data manipulative device capable of providing an information environment in which any number of process simulators, of which AIMS is one, may effectively operate. This is the core concept of the accountability system.

The system specifications previously listed for the Generalized Educational Management System are likewise applicable to AIMS. As typical specifications representing needs in two other areas, pedagogy and behavioral psychology, the selected examples which follow may be of interest. The items have been chosen out of a range utilized in an application of AIMS at the United States Naval Academy, Annapolis, Maryland.

1. Typical Pedagogy Specifications:

   a. Produce a listing of all students registered in the program; provide options at user choice so listing can be arranged alphabetically, in the order of the student I.D. number, as a single list, or divided into the separate class sections.

   b. Produce a complete listing of the answer matrices for all tests: include the MBO[2] reference and a brief description of the MBO; the remedial prescription is also to be listed for each wrong answer by noting book number, page number, and problem number of the assignment.

   c. Produce an individual student test print-out; in a format allowing the report to be given directly to the student after a test has been processed; include, in addition to the identifying heading, the truth value of each answer choice; in addition to remedial assignment, a personal message of encouragement or censure is to be included depending upon the student's grade; also, include a direction to report to the laboratory for a special remedial lesson if necessary.

   d. Provide an individual student rating for homework as totals, or recaps of the number of A, B, C, D, and E ratings that were assigned to each of the homework problems by the homework markers over a given period of time.

   e. Provide individual homework rating scores, student and section, give the number of A, B, C, D, and E grades issued to each student in each section for one particular homework assignment, where each letter is assigned a weight and the total score is converted to an average percentage.

f. Format a student profile, the form giving a summary of all the test scores and homework scores, as well as the current average, of each student in each section; provide update capacity after each entry so as to provide a running profile of each student's performance.

g. Structure histograms, the frequency distribution bar graph that shows the number of students that received each of the test scores assigned, to summarize the total performance record on any individual test for quick visual analysis of the entire student population.

h. Provide item analysis so as to maintain a record of the number of students that chose each of the answers that were presented in the multiple choice format of the test, with flagging to indicate the areas that need investigation.

i. Provide parameter flagging, with output devised to assist the investigator in examining the item analysis. Certain parameters are to be selected to determine answers chosen by more than 90% of the students, distractors chosen by 0% of the students, and distractors chosen by more than 25% of the students

j. Determine final grade by variable selection of the computer marked, multiple choice objective test scores, homework grades, hand-graded trisemester tests, and the final, hand-graded examination made, averaged, and weighted to arrive at a term mark.

k. Calculate and list indices and deviations for the group and individual as follows:

Group:

- Capability Index
- Performance Index
- Performance Deviation
- Problem Achievement
- Post Test Achievement
- Net Achievement
- Achievement Deviation

Individual:
    Capability Index
    Performance Index
    Absolute Performance Deviation
    Relative Performance Deviation
    Problem Achievement
    Post Test Achievement
    Net Achievement
    Absolute Achievement Deviation
    Relative Achievement Deviation

l. Calculate and list mean indices as follows:

Cumulative Mean Problem Achievement
Cumulative Mean Post Test Achievement
Cumulative Mean Net Achievement

m. List MBOs in each lesson to contain the following:

(1) Each EO in the study guide which requires more than one trial selection to achieve the correct response.

(2) Each EO in the worksheet for which the criterion question is incorrectly answered.

(3) A remedial prescription for each of the items in A and B in the form of reference to three standard textbooks and the pages where the material contained in the EO may be found.

(4) Each TO which is not satisfactorily met in the Post Test.

(5) A remedial prescription for each TO as prescribed above.

n. For those students who attain relative performance and relative achievement indices of +20 or more, provide a congratulatory message and an optional assignment of enrichment material in the form of textbook readings, advanced films, and/or advanced audio tapes.

o. For those students who attain a relative achievement index of +30 or more, provide a congratulatory message and an optional assignment as indicated above; and, in addition, include a statement that he has attained tutorial status and may be assigned to assist other students in the group.

p. Provide an item analysis based on study guide worksheet performance of the group which enables the instructor to organize his group multiple media instruction (GMI) session for the week.

q. Provide an item analysis based on homework problems and post test which further contributes to instructional decision for the GMI session.

r. Structure skill category analysis for each student which enables the instructor to select specific weaknesses to be attacked by tutorial assistance.

s. Provide a media category analysis for each student which enables the course designer as well as the instructor to select remedial media and enrichment media for individual student use.

t. Divide each group into quartiles based on net achievement in each lesson.

u. For each quartile display the percentage of students who:

   (1) Needed more than one try before arriving at the correct answer to each study guide criterion check.

   (2) Answered each worksheet question incorrectly.

   (3) Received A, B, C, D, and E on each homework problem set.

   (4) Answered each post test question incorrectly.

v. For each quartile display the percentage of students who scored well or poorly on questions dealing with each of the four media categories.

w. For each quartile display the percentage of each of the skill levels correctly handled by the students.

2. Typical Behavioral Psychology Specifications

   a. Produce a matrix which shows the relationship between TO, EO, learning or skill category,

b. Provide for selection and/or extraction of students into experimental groups based on characteristics reflected in their data.

c. Provide a management system capability for at least 1200 students.

d. Provide for the maintenance of a student background data file including:

    Past Academic History
    Student Interest Profile
        Edwards Preference
    Aptitude Profile
        SAT Scores
        Achievement Scores
        Reading Level

e. Provide for collection of student timing information.

f. Allow information input from:

    Mid-term exam
    Final exam
    Topic or lesson
    Pre-test
    Post-test
    Monitor of classroom performance
        (or analogy)

g. Provide capability to perform following statistical analysis on selected groups of students:

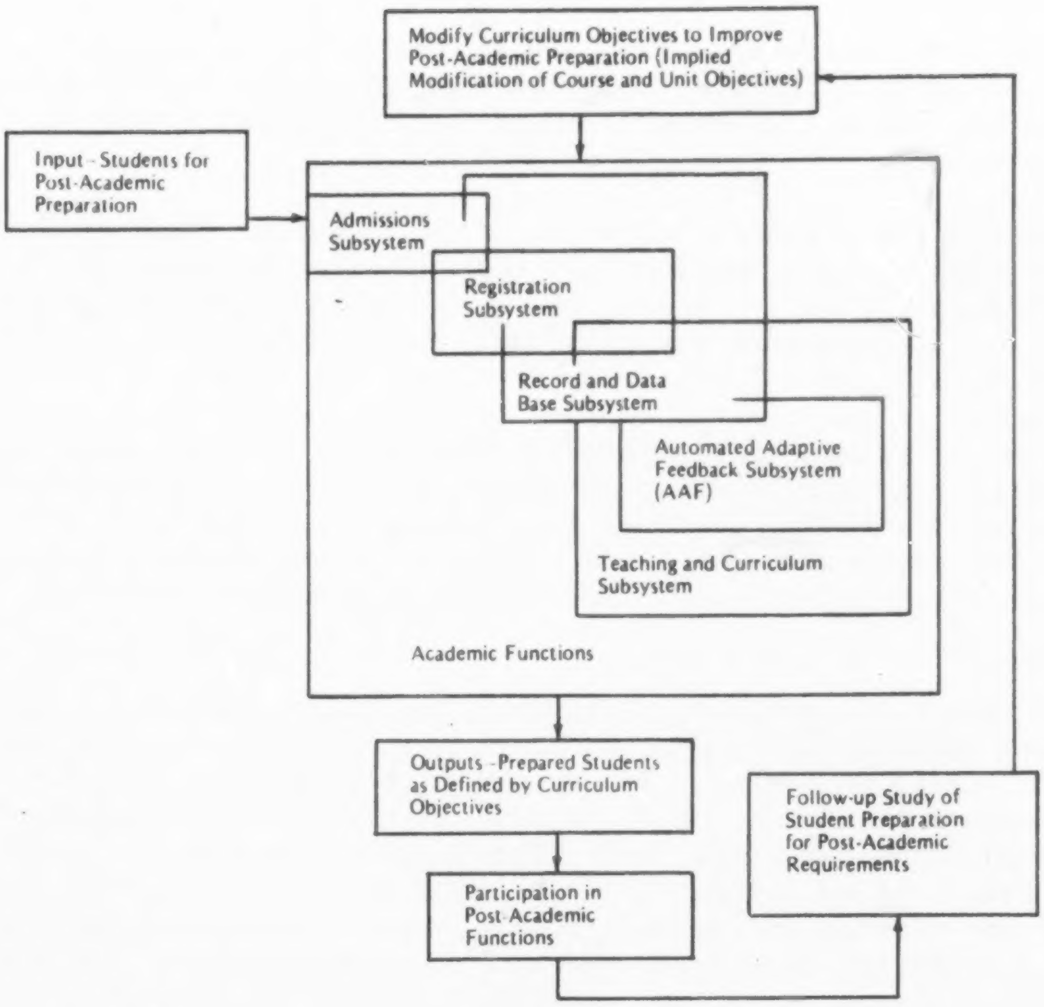
    Analysis of Variance
    Item Analysis
    Kuder-Richardson Analysis
    Correlation of Wide Spread Classes
    T-Test of Means and Differences
    Linear Regression Analysis
    Pearson and Rank Correlation
    Covariance Analysis
    Multiple Regression Analysis

h. Develop mathematical basis for empirical simulation model for student guidance and forecasting performance.

## F. ADDITIONAL EVALUATIVE SYSTEM CHARACTERISTICS

The simplified schematic of Figure 4 indicates essential requirements of an educational environment. Basically, we begin with students to be educated, structure varied environmental arrangements

Figure 4


Modify Curriculum Objectives to Improve Post-Academic Preparation (Implied Modification of Course and Unit Objectives)
Input – Students for Post-Academic Preparation
Admissions Subsystem
Registration Subsystem
Record and Data Base Subsystem
Automated Adaptive Feedback Subsystem (AAF)
Teaching and Curriculum Subsystem
Academic Functions
Outputs – Prepared Students as Defined by Curriculum Objectives
Participation in Post-Academic Functions
Follow-up Study of Student Preparation for Post-Academic Requirements

to prepare students to function successfully in post academic situations, and, then evaluate successes and failures, with varied criteria, to see what modifications are necessary for the totality being examined. As an example, evaluators of technical programs are concerned with the ability of graduates to be accepted, function, adjust and progress in the industries or society offering opportunities for which they have been prepared by the educational environment. All the elements encompassed within the environment, including pupils, facilities, teachers, courses, resources and other relevant factors, are adjusted when the total process does not yield the broad objectives set for the educational system under scrutiny. Thus, if an automotive technology program failed to produce industry acceptance or retention for the majority of its students, the entire program would be scrutinized rather than any single component.

Figure 5 shows salient elements of the Adaptive Feedback System and Figure 6 represents a component of the Automated Adaptive Feedback System applied to a course. Again, it is emphasized, the criteria for measurement of effectiveness are those selected by the users. Someone might select as a principal criteria the upward shifting of the "normal" achievement curve, plotted against delineated objective measures, for successive offerings of a program. (Figure 7) Another individual might select reduction of student attrition by curriculum modification as the principal criteria. (It has been alleged that 10% of course content has been responsible for 90% of attrition and failure in certain occupationally related skill areas in some military training centers.)

The impact of important elements affecting educational systems are sometimes underemphasized, or unstudied, possibly because of the complexity of their inclusion. Educators require a system provision to yield meaningful information which will assist in decision-making under stressed political situations. The usual inadequacy of information for this critical function is an important reason for the reluctance of individuals and communities to stand accountable for their programs. A potential simulation model of the communities concerned, with computer analyses techniques equivalent to the voter profile approaches characterizing election forecasting, is shown in Figure 8. The interrelationship to instructional process subsystems is amplified in Figures 9 and 10 which give further evaluation approaches to given educational situations.

The purpose of each component described above is to produce those quantifiable measures, individual or composite, which determine the effectiveness of the instructional system. While different system users may weight the information produced in terms of their priorities, the baselines produced would always be quantitative and specific.

## G. THE GUIDANCE MODEL

The guidance model, ULTRA, illustrates the accountability system further as it operates at New York Institute of Technology. ULTRA occupationally oriented at Tech, is a model which can be applied to

*Figure 5*

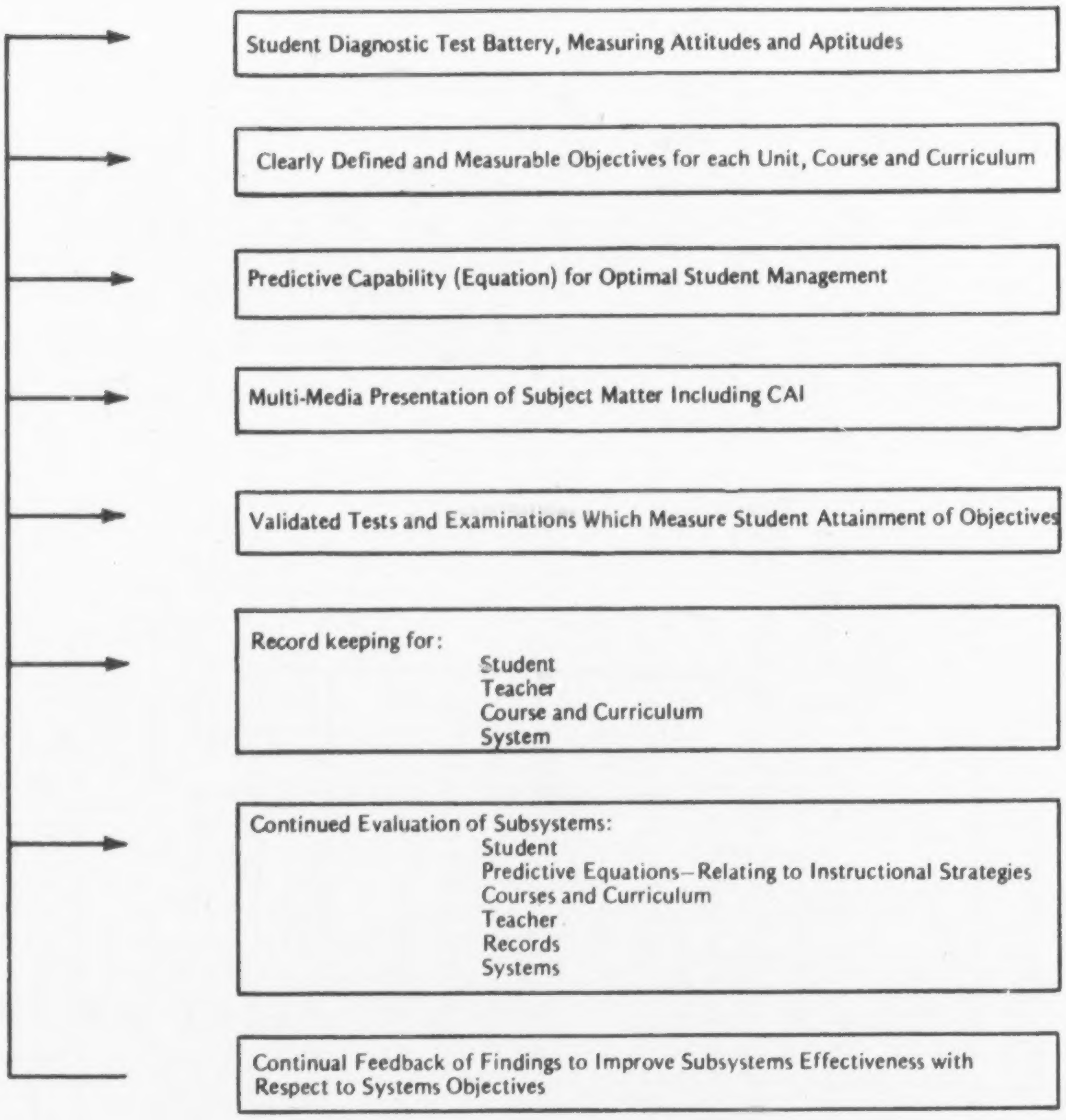

Student Diagnostic Test Battery, Measuring Attitudes and Aptitudes
Clearly Defined and Measurable Objectives for each Unit, Course and Curriculum
Predictive Capability (Equation) for Optimal Student Management
Multi-Media Presentation of Subject Matter Including CAI
Validated Tests and Examinations Which Measure Student Attainment of Objectives
Record keeping for:
Student
Teacher
Course and Curriculum
System
Continued Evaluation of Subsystems:
Student
Predictive Equations—Relating to Instructional Strategies
Courses and Curriculum
Teacher
Records
Systems
Continual Feedback of Findings to Improve Subsystems Effectiveness with Respect to Systems Objectives

*Figure 6*

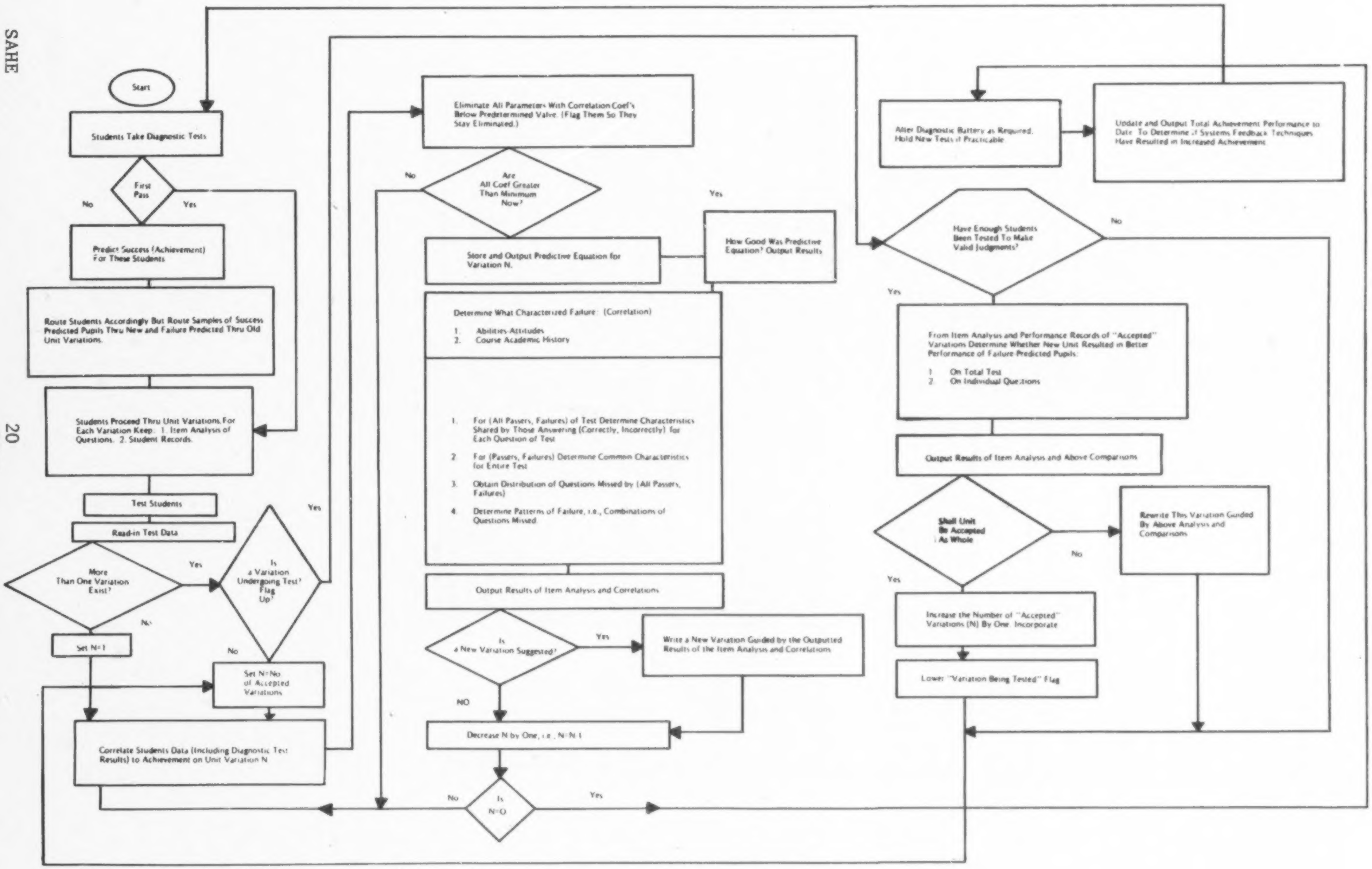

Start
Students Take Diagnostic Tests
First Pass
No
Yes
Predict Success (Achievement) For These Students
Route Students Accordingly But Route Samples of Success Predicted Pupils Thru New and Failure Predicted Thru Old Unit Variations.
Students Proceed Thru Unit Variations For Each Variation Keep: 1. Item Analysis of Questions. 2. Student Records.
Test Students
Read-in Test Data
More Than One Variation Exist?
Yes
No
Set N=1
Is a Variation Undergoing Test? Flag Up?
Yes
No
Set N=No of Accepted Variations
Correlate Students Data (Including Diagnostic Test Results) to Achievement on Unit Variation N
Eliminate All Parameters With Correlation Coef's Below Predetermined Valve. (Flag Them So They Stay Eliminated.)
Are All Coef Greater Than Minimum Now?
No
Yes
Store and Output Predictive Equation for Variation N.
How Good Was Predictive Equation? Output Results
Determine What Characterized Failure: (Correlation)
1. Abilities-Attitudes
2. Course Academic History
1. For (All Passers, Failures) of Test Determine Characteristics Shared by Those Answering (Correctly, Incorrectly) for Each Question of Test
2. For (Passers, Failures) Determine Common Characteristics for Entire Test
3. Obtain Distribution of Questions Missed by (All Passers, Failures)
4. Determine Patterns of Failure, i.e., Combinations of Questions Missed
Output Results of Item Analysis and Correlations
Is a New Variation Suggested?
Yes
NO
Write a New Variation Guided by the Outputted Results of the Item Analysis and Correlations
Decrease N by One, i.e., N=N-1
Is N=O
No
Yes
Alter Diagnostic Battery as Required. Hold New Tests if Practicable
Update and Output Total Achievement Performance to Date To Determine if Systems Feedback Techniques Have Resulted in Increased Achievement
Have Enough Students Been Tested To Make Valid Judgments?
No
Yes
From Item Analysis and Performance Records of "Accepted" Variations Determine Whether New Unit Resulted in Better Performance of Failure Predicted Pupils:
1 On Total Test
2 On Individual Questions
Output Results of Item Analysis and Above Comparisons
Shall Unit Be Accepted As Whole
No
Yes
Rewrite This Variation Guided By Above Analysis and Comparisons
Increase the Number of "Accepted" Variations (N) By One. Incorporate
Lower "Variation Being Tested" Flag

Figure 7

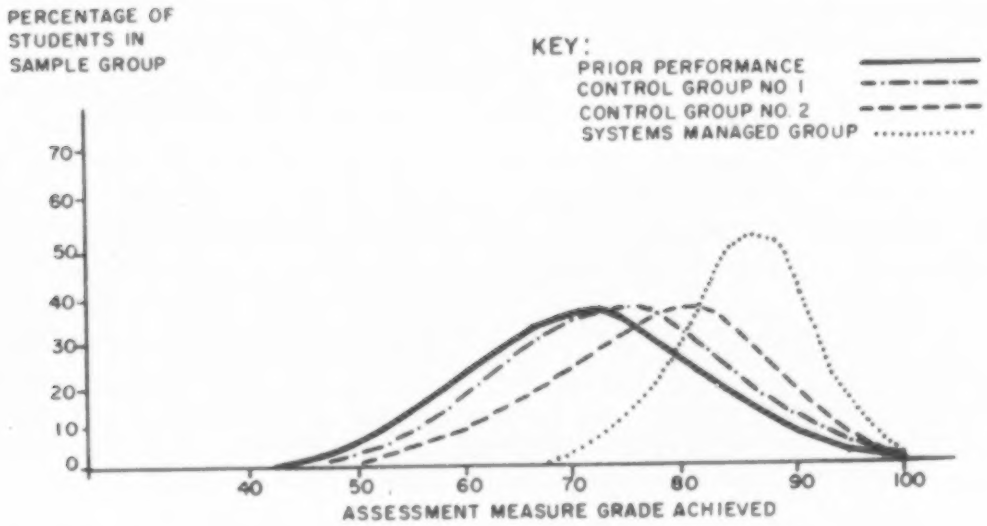
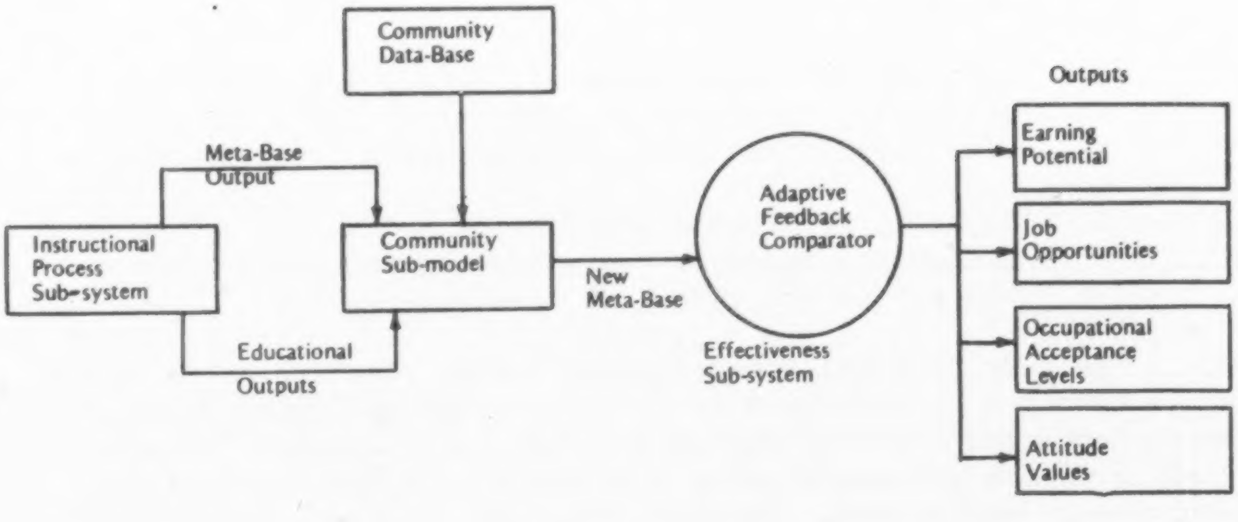


Figure 8


Community Data-Base
Outputs
Meta-Base Output
Instructional Process Sub-system
Community Sub-model
New Meta-Base
Adaptive Feedback Comparator
Effectiveness Sub-system
Educational Outputs
Earning Potential
Job Opportunities
Occupational Acceptance Levels
Attitude Values

the guidance and control of a student through any educational environment. Operating within a central information system such as SAFES, enough flexibility exists so as to allow ULTRA to provide basic guidance information as well as supervised management of students involved in elementary, secondary and collegiate education. The purpose of ULTRA is for each student to receive the education, that is, environment, courses and curriculum, which will qualify him for the career objective selected by his interests and potential abilities as diagnosed, discussed, predicted, and interpreted by the combined attributes of man-made examination, computer-oriented methodologies, and man-machine interpretations, with final human decision-making approval. ULTRA has, as one of its fundamental objectives, the organization of obtainable pathways by means of which each individual may expect a high probability of realizing the predicted match of this potential with the occupational, scholastic, and curriculum opportunities available to him. The resulting procedures can guide those concerned with the learning process through the major steps of optimized educational decision-making with respect to occupational guidance. The ULTRA schematic (Figure 11) shows varied routes available either for student guidance assignment or achievement of desired educational results. The computer, when used in a guidance management process, focuses factors as:

1. The translation of desired end point job skills in terms of student performance which the training is to bring about;

2. Establishment of prerequisite entry level skills;

3. Detailed task analyses which stipulate testing measures to verify performance;

4. Predictive measures to develop criteria of performance coupled to recommendations for the kinds of instruction, strategies and guidance which will best overcome each learner deficiency;

5. Cost effectiveness measures, to provide a means of evaluating "success" in terms of dollar cost, pupil time expenditures, or other pertinent criteria;

6. Capacity to provide information sufficient to operate a complete manpower management system encompassing the school and community resources.

As part of ULTRA, the computer serves researchers as an aid in the creation of individually oriented programs for students who desire technical careers, including those whose success in conventional programs is questionable. Students in ULTRA are admitted, interviewed, and tested. The resulting data are sent to a computerized information center where a personal profile is constructed for each student. The profile encompasses records of ability, skills, knowledge, and a prediction of the student's future performance. Guidance counselors design a student's individual program on the basis of his profile, interview, and computer recommendations.

Students with the immediate capacity for college work are enrolled in programs leading to the two-year associate or four-year bachelor's degrees in various specialized technical fields. Others are referred to a diagnostic center where they undergo further examination. On the basis of test results, they enter two or four-year programs combining regular courses and remedial studies to overcome academic weakness. Students indicating marked deficiencies are enrolled in an intensive pre-college program prior to the pursuit of college-level courses. Those unable to undertake college work are placed in an "alternate skills" program combining jobs in cooperating industries with off-campus studies. The "alternate skills" program enables future transfer to college-level academics.

One paramount aspect of project ULTRA is the continuous assessment of individual progress. Test scores, learning rates, and acquired skills are constantly recorded and fed back to the teaching staff by the computer. An instructor need not wait until the conventional midterm or final for an over-view of his students' progress. Such intensive assessments allow staff members to refine predictive techniques and alter a student's curriculum where necessary. Work-study students can, thus, be transferred to college and advanced training. A student with a poor chance for success in a given program may be channeled into a program where success is more probable. Project ULTRA retains face-to-face counseling; it has, in addition, demonstrated that computers can keep guidance and evaluative requirements for a diversified student body within feasible economic bounds.

## H. THE INSTITUTIONAL MANAGEMENT INFORMATION SYSTEM

The Institutional Management Information System (IMIS), another of the GEM subsystems, performs the function of central administration and library management on an institutional level. However, the institution may be defined as an elementary or secondary school, a vocational institution, a school district, a small college, a university, or even a state-wide educational network. This diversity of application is attributable to the principle of modularity and the innate flexibility of SAFES. Program modules having varied functions can be inserted into or extracted from the system without affecting the integrity of the totality. SAFES will then modify the data environment to accommodate the new function.

Within the province of central administration are the functions of grade reporting, admissions, registration, scheduling, student accounting, plant and equipment maintenance, inventory control, payroll, general accounting, purchasing and the library functions of cataloging, circulation control and information retrieval.

## I. THE PROGRAM MANAGEMENT INFORMATION SYSTEM

In addition to the administrative systems operative under GEMS, a number of simulation devices can be used in augmenting the system to provide management information in specific areas. One such simulation device developed by the Advanced Systems Group is PROMIS (Program Management Information System).[3] PROMIS is a planning,

*Figure 9*

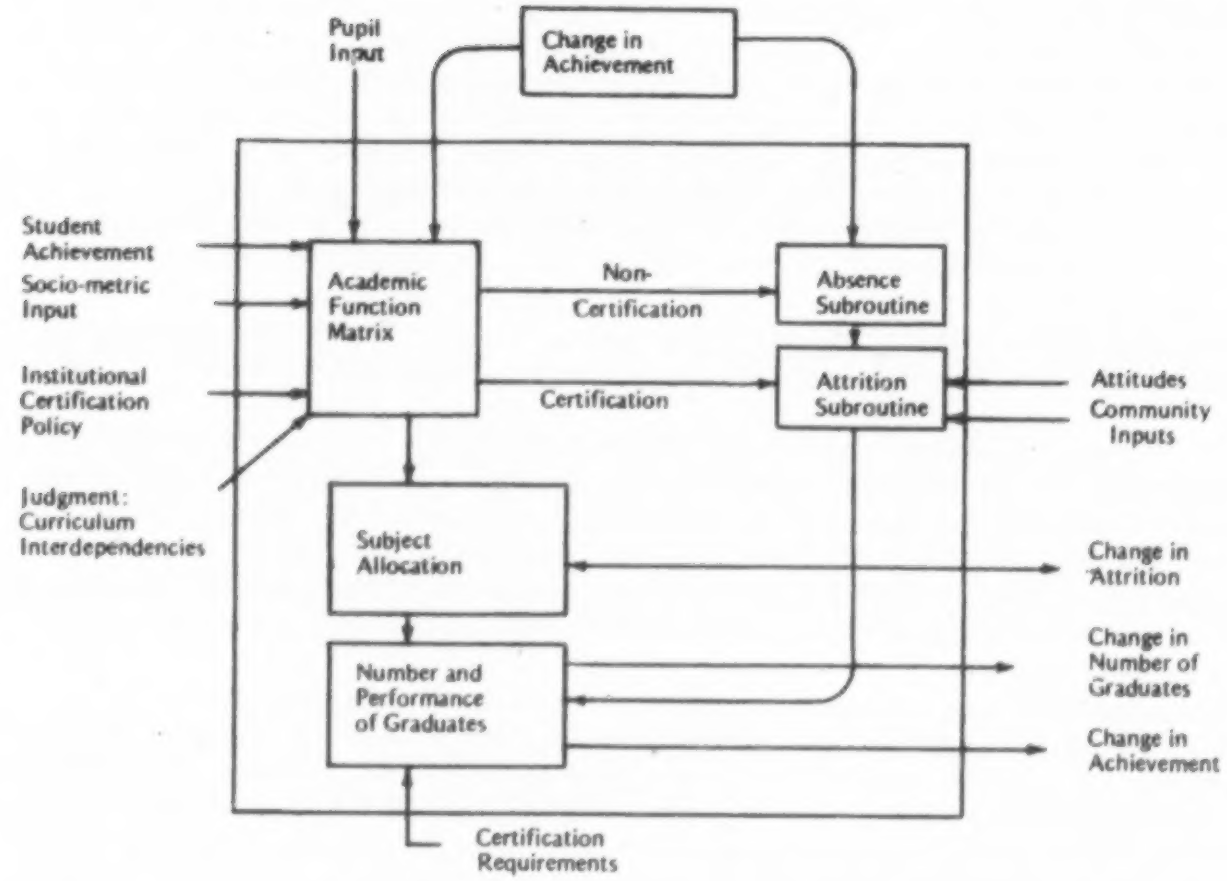

Pupil Input
Change in Achievement
Student Achievement
Socio-metric Input
Institutional Certification Policy
Judgment: Curriculum Interdependencies
Academic Function Matrix
Non-Certification
Certification
Absence Subroutine
Attrition Subroutine
Attitudes
Community Inputs
Subject Allocation
Change in Attrition
Number and Performance of Graduates
Change in Number of Graduates
Change in Achievement
Certification Requirements

*Figure 10*

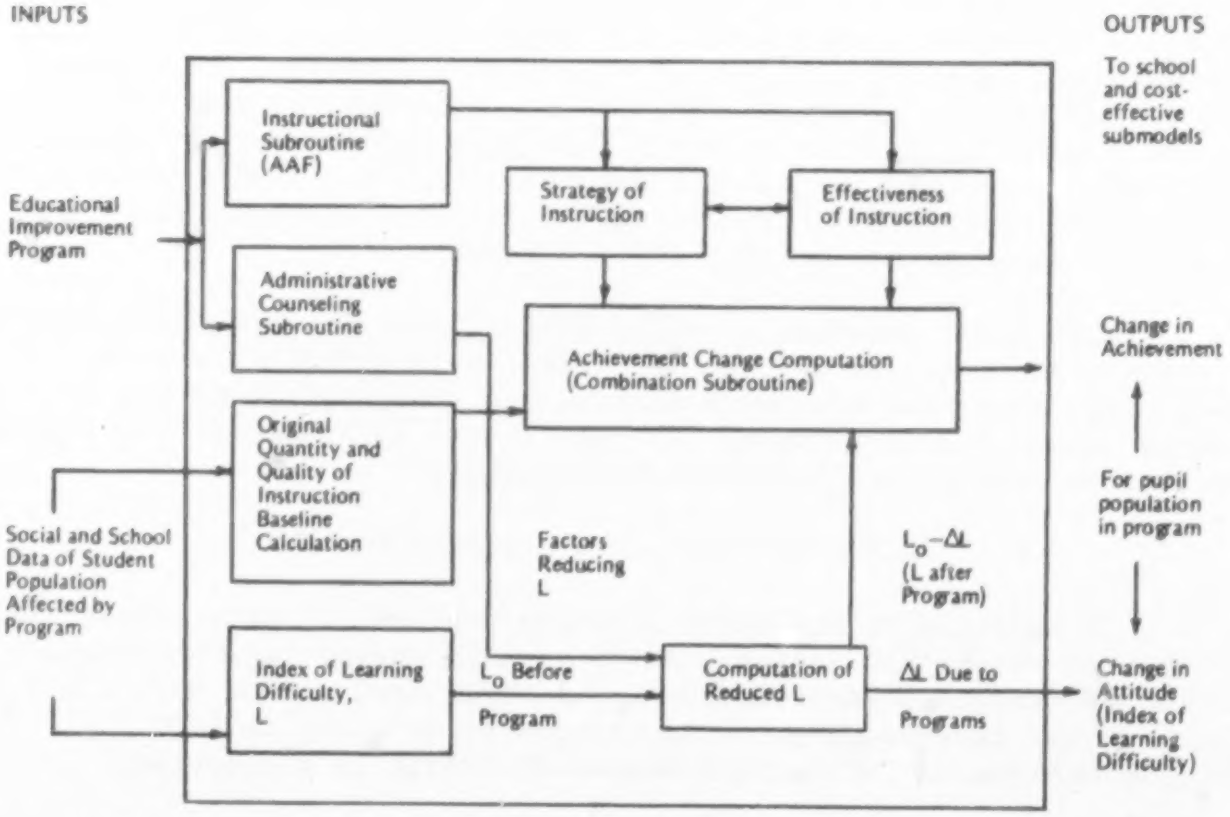
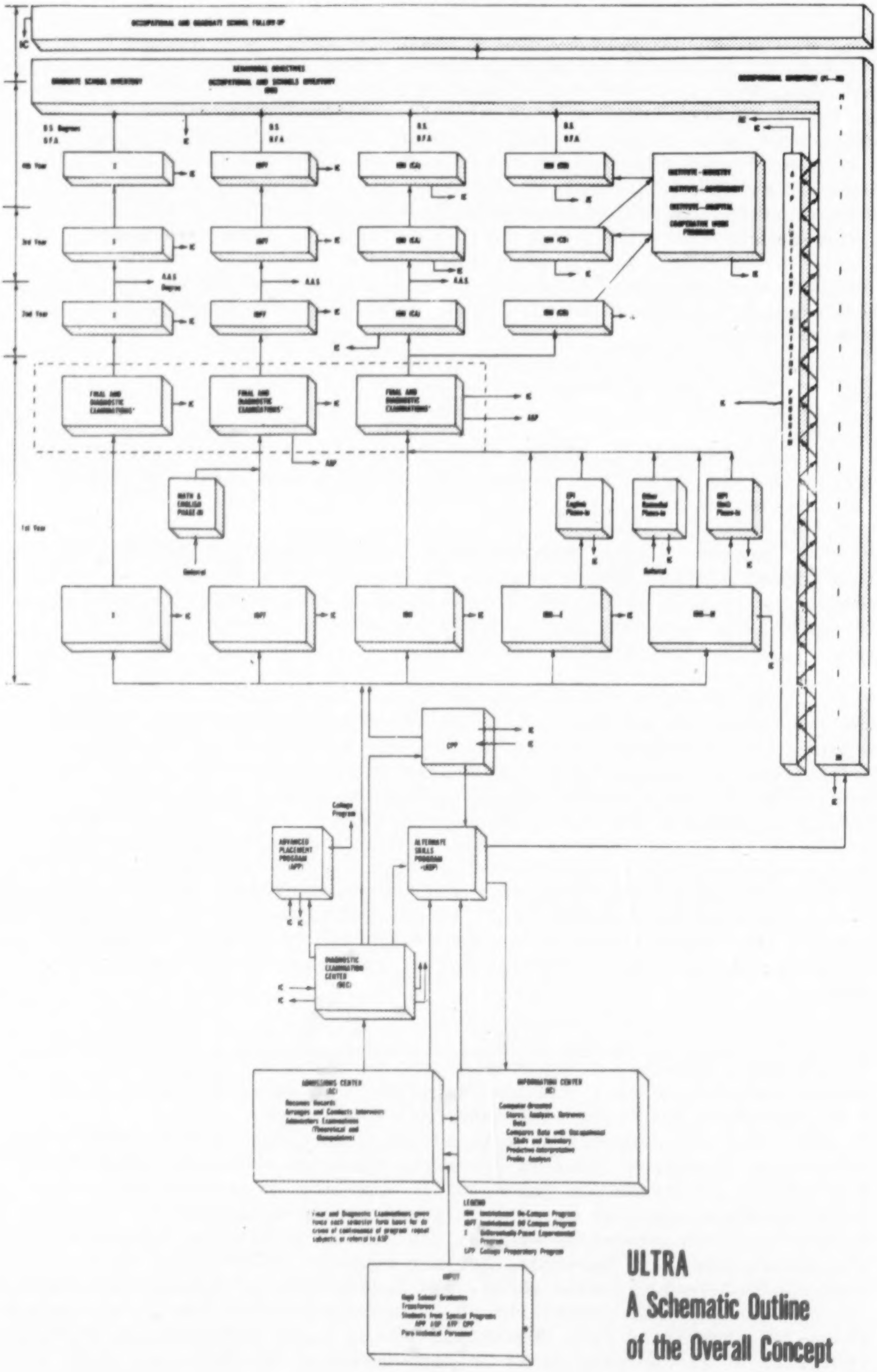

INPUTS
OUTPUTS
To school and cost-effective submodels
Educational Improvement Program
Instructional Subroutine (AAF)
Strategy of Instruction
Effectiveness of Instruction
Administrative Counseling Subroutine
Achievement Change Computation (Combination Subroutine)
Change in Achievement
Original Quantity and Quality of Instruction Baseline Calculation
For pupil population in program
Social and School Data of Student Population Affected by Program
Factors Reducing L
$L_o - \Delta L$ (L after Program)
Index of Learning Difficulty, L
$L_o$ Before Program
Computation of Reduced L
$\Delta L$ Due to Programs
Change in Attitude (Index of Learning Difficulty)

Figure 11


IC
4th Year
3rd Year
2nd Year
1st Year
B.S.
B.F.A.
A.A.S. Degree
A.A.S.
FINAL AND DIAGNOSTIC EXAMINATIONS*
ASP
MATH & ENGLISH PHASE-IN
Referral
College Program
ADVANCED PLACEMENT PROGRAM (APP)
ALTERNATE SKILLS PROGRAM (ASP)
DIAGNOSTIC EXAMINATION CENTER (DEC)
CPP
ADMISSIONS CENTER (AC)
Receives Records
Arranges and Conducts Interviews
Administers Examinations (Theoretical and Manipulative)
INFORMATION CENTER (IC)
Computer Oriented
Stores, Analyzes, Retrieves Data
Compares Data with Occupational Skills and Inventory
Predictive Interpretation
Profile Analysis
* Final and Diagnostic Examinations given twice each semester form basis for decisions of continuance of program, repeat subjects, or referral to ASP
LEGEND
IOC Institutional On-Campus Program
IOFT Institutional Off-Campus Program
E Differentially-Paced Experimental Program
CPP College Preparatory Program
INPUT
High School Graduates
Transferees
Students from Special Programs
APP ASP ATP CPP
Para-technical Personnel

## ULTRA
## A Schematic Outline of the Overall Concept

programming, budgeting simulator designed to provide information on the cost of projected implementations of educational programs. In addition, when provided with allowable variations in program elements, it will produce a range of optimal and suboptimal program implementations based solely on cost analysis. Although capable of accepting a wide range of input information, when a modified PERT input is provided, greatest information yield is attained. This system can be applied to generating cost projections and optimum implementation patterns for a wide variety of programs such as an analysis of a model elementary teacher training program, projected curriculum changes involving new or reallocated teaching staff, with consequent impact upon facilities, building and space allocation proposals.

## IV. CONCLUSION

It has been the intent of this paper to describe a philosophy and initial application of an accountability system which can aid in coping with the problems of our occupationally related schools.

The very nature of educational effectiveness is complex and goes beyond simple indices such as the relationship of cost to productive output. The problems confronting researchers attempting to quantify and measure the intangible qualities of education are formidable, but not unsurmountable.

The totality of all relevant questions relating to accountability cannot be answered by any single model. Any selected model is only an abstraction of selected factors and characteristics of an environment, embodying a stated opinion as to probable relationship. Yet the process has validity, for the model, be it good or bad, is a tangible structure capable of being tested. Its closeness to the world of reality can usually be precisely determined for when it operates well it forecasts probable occurrences accurately and when it fails it can be modified, retested and reevaluated. Empirically, the pattern can be repeated until a basis of effectiveness exists wherein the effectiveness of change in any of the model's components can be evaluated against the indicators important to the use of the model.

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[1] O'Dierno, Ernest. *A Progress Report on the Development of a Generalized Educational Management System.* Advanced Systems Laboratory, New York Institute of Technology, April 1969.

[2] MBO. For the purposes of this system discussion, a Measurable Behavioral Objective (MBO) is a generic term for a Terminal Objective (TO) or any of its associated specific Enabling Objectives (EO).

[3] An in-depth utilization of this simulator is described in: Final Report, U.S. Department of Health, Education and Welfare, Office of Education, Bureau of Research, Project Number: OE-90415, Contract Number OEC-0-9-450415-4045 (010), *The Feasibility of Educational Specifications for the Ohio Comprehensive Elementary Teacher Education Program* Phase II. Submitted by a Consortium of the State Universities of Ohio. Published at the University of Toledo, December 31, 1969, pp. 1-88.

# 3

# ADAPTIVE INSTRUCTIONAL MANAGEMENT SYSTEM

*A model computer-based system for the management of the educational process.*

## AUTOMATED INSTRUCTION MANAGEMENT SYSTEM

### Table of Contents

I. OVERVIEW .................................... 1

II. AIMS III STATUS ................................ 2

III. GENERAL OBJECTIVES ............................ 3

IV. REVIEW OF INFORMATION PRODUCED ................. 4

V. INPUT REQUIREMENTS ............................. 11

VI. DESCRIPTION OF OUTPUT .......................... 12

VII. THE CURRENT STATUS OF OPERATIONS OF AIMS III ... 22

VIII. CONCLUSION AND EXTENSION ...................... 24

IX. DEVELOPMENT OF PREDICTOR EQUATIONS ............. 25

X. SIMULATION LOGIC ............................... 32

XI. DOCUMENTATION AVAILABILITY ..................... 33

APPENDIX ........................................ 34

GLOSSARY ........................................ 50

## ADAPTIVE INSTRUCTIONAL MANAGEMENT SYSTEM

### Table of Figures

FIGURE 1 - Post Test ...................... 5

FIGURE 2 - Volume Submittal ............... 6

FIGURE 3 - Class TO Performance ........... 7

FIGURE 4 - Volume Summary ................. 8

FIGURE 5 - Item Analysis .................. 9

FIGURE 6 - Histogram ......................10

FIGURE 7 - Course Structure ...............13

FIGURE 8 - TO Cutoff Level ................14

FIGURE 9 - Student TO Performance .........16

FIGURE 10 - Class TO Performance ..........16

FIGURE 11 - TO Remedial Lesson Plan .......17

FIGURE 12 - Assignment to Remedial Sessions ....................18

FIGURE 13 - Class Roster ..................19

FIGURE 14 - General Volume Statistics ..................20

FIGURE 15 - Individual Statistical Volume Summary ..............21

# I. OVERVIEW

The Automated Instruction Management System (AIMS) has been designed to monitor, score, and evaluate individual students, groups of students, and curricular content in a course environment designed for educational management. Design philosophy includes providing course administrators with a meaningful analysis, and constructive assessment of student or group performance, within the environment of a course created for computer management. Since the system requires a minimum of "installation tailoring," AIMS is capable of servicing most user requirements once adapted to the course environment. Through its modular construction, it is possible to incorporate other student input techniques for time-shared and teleprocessed implementation.

AIMS Version III was generated to be as versatile as possible, without prohibitive INPUT/OUTPUT requirements. To insure versatility and compatibility, it was designed around IBM System/360, and was generated with the Model 30/Release 20 IBM Disk Operating System (DOS).

The overall design concepts governing the development of AIMS constitutes:

- Machine independence to the maximum possible extent can be adapted to a wide variety of machine configurations.
- Creating, maintaining and accessing a large data-base, relevant to student curricular, pedagogical, and administrative aspects of a given scholastic environment.
- Creating, maintaining, and accessing subfiles containing meta-data
- Providing printed analyses of past current, and future student progress throughout the scholastic environment
- Generating an adaptive feedback loop through which the system can modify its multiple-model simulator to reflect current conditions within its subfiles.

The system, through the media of feedback and analysis, incorporates the necessary procedures for updating and optimizing the general level of instruction and testing

Extending into the Behavioral Psychology environment enables AIMS to produce a matrix showing the relationship between Terminal Objectives and Enabling Objectives learning or skill category, media type, and each individual question. The inclusion of a validation capability has made AIMS the ideal vehicle for experimental curriculum analysis.

The ultimate aspiration in the development of the AIMS System, is toward the achievement of a Generalized Educational Management System (GEM), designed to encompass the totality of the educational environment in which it operates. GEM is based on an advanced data file access/retrieval system, with innate adaptive feedback characteristics. The Sequential Access File Entry System (SAFES) provides data-base capable of supporting the operation of virtually any kind of process model. A generalized simulator, which effectively becomes a unique computer language, could be used to develop models of a wide range of educational environments, emulating discrete aspects of the education sphere.

The basic structure of a Generalized Educational Decision Structure (GEDS) is created, and specified, as educational process information is fed into the system. Upon specification, the simulator reduces to a model of an aspect of the educational environment. Four such models, which can be generated by the simulator, are:

- Community Subsystem...providing output of Earning Potential, Job Opportunities, Occupational Acceptance Levels and Attitutde Values

- Instructional Process Subsystem...resulting in Change in Attrition, Change in the Number of Graduated, and Change in Achievement output information.

- Cost Subsystem...giving Total Program Effectiveness, Improved Resources, and a Computed Cost Listing as end products.

- Instructional Process Input System...for the pupil population in the program, outputs Change in Achievement, Change in Attitude (index of learning difficulty) to School, and Cost Effective Submodels.

## II. AIMS III STATUS

1. AIMS III is organized, developed, and refined as a computer monitoring system through application of the Systems Analysis technique.

2. It is currently operational at the New York Institute of Technology.

3. It is monitoring separate courses simultaneously, demonstrating its replicability and adaptability.

4. It is structured to accommodate a self-paced mode of instruction and to provide statistics for individualization and optimization of the course.

5. The accounts of the project are being disseminated with constant demonstrations of the operation.

## III. GENERAL OBJECTIVES

The objectives of the Automated Instructional Management System (AIMS) are to interact in appropriate ways with three groups of individuals. These are the student, the instructor/course manager and the course designer/creator.

1. The objective of the relationship between the student and the AIMS III system is to provide the student with responsibe interaction and information as to his performance within the lesson. In addition, the system provides the student with an appropriate presentation of remedial information.

    a. The presentation of this information functions to guide the student in the selection of alternative learning materials and activities.

    b. Modern American education is progressing very rapidly in the direction of individualized instruction. In a self-paced environment it becomes incumbent upon the teacher to be constantly aware of the individual performance of each student and the group of students.

        (1) This activity alone frequently reduces the teacher to the role of a clerk, with little time for the *teaching* functions.

2. For the course instructor, the AIMS System does several tasks.

    a. It provides the clerical monitoring function.

    b. It permits the teacher time and facilities for the in-depth evaluation of the effectiveness of the learning which is occurring within the class.

    c. It permits the teacher time to perform in a consultative role with the students.

d. The system provides reports which supply a detailed history of the performance of each student so that his progress can be examined frequently.

(1) Appropriate interactions with other students, individualized learning materials, or the instructor may be scheduled.

3. The third target subject for the automated instructional management system is the course designer. It is the objective of the system to feed information back to the course designer which will permit him to revise the course design within the environment in which it is being presented.

a. In order to accomplish this, the AIMS III System provides a series of reports. These reports supply to the course designer:

(1) Information as to detailed performance of the group of students upon any given behavioral objective or set of behavioral objectives;

(2) Validation of the criteria used to inquire as to the students' performance or nonperformance of a given behavioral objective;

(3) Information as to the overall effectiveness of the learning techniques supplied.

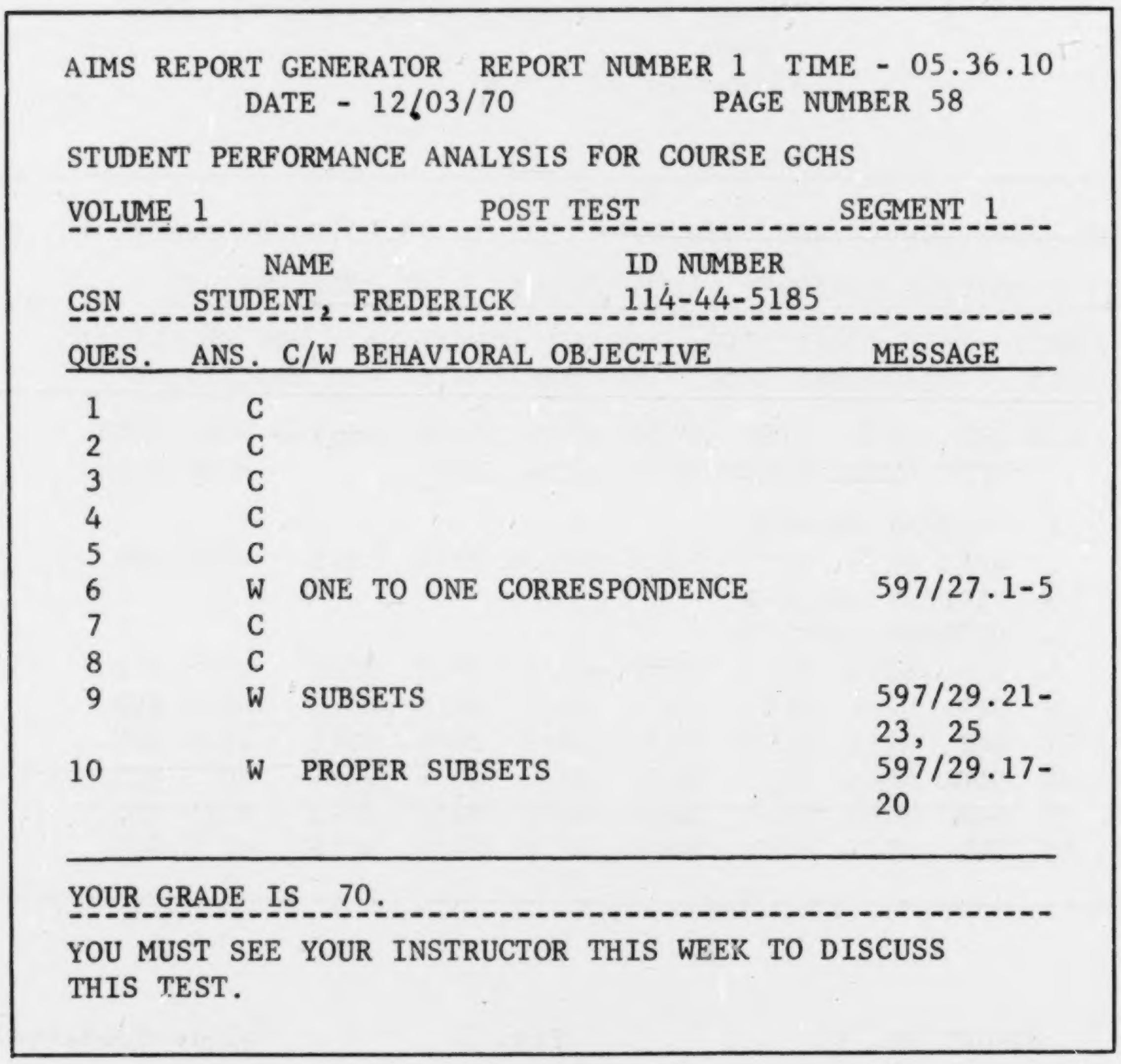
## IV. REVIEW OF INFORMATION PRODUCED

The reports provided by the AIMS III System which are directly relevant to the three target groups include the following:

1. FOR THE STUDENT:

a. A report is issued indicating areas of strength and weakness in his performance on a given set of criteria which measures his degree of accomplishment of one or a set of behavioral objectives.

(1) This report also gives to the student remedial prescriptions (message) which are keyed to those areas in which he failed to perform satisfactorily. (See Fig. 1)



```
AIMS REPORT GENERATOR  REPORT NUMBER 1  TIME - 05.36.10
            DATE - 12/03/70          PAGE NUMBER 58

STUDENT PERFORMANCE ANALYSIS FOR COURSE GCHS

VOLUME 1                 POST TEST              SEGMENT 1
---------------------------------------------------------
             NAME                    ID NUMBER
CSN    STUDENT, FREDERICK            114-44-5185
---------------------------------------------------------
QUES.  ANS. C/W BEHAVIORAL OBJECTIVE            MESSAGE

 1          C
 2          C
 3          C
 4          C
 5          C
 6          W   ONE TO ONE CORRESPONDENCE       597/27.1-5
 7          C
 8          C
 9          W   SUBSETS                         597/29.21-
                                                23, 25
10          W   PROPER SUBSETS                  597/29.17-
                                                20
_________________________________________________________

YOUR GRADE IS  70.
---------------------------------------------------------
YOU MUST SEE YOUR INSTRUCTOR THIS WEEK TO DISCUSS
THIS TEST.
```

Report No. 1          Fig. 1          Post Test

Note: For a description of the purpose and use of this printout, see page 12.

b. Another report can also give the student information as to an appropriate environment in which to obtain remediation for those behavioral objectives in which his performance is not yet adequate.

2. FOR THE COURSE INSTRUCTOR:

   a. A report is provided which supplies the instructor with information as to which students have submitted material for each of the different sections of the course.

      (1) This permits the instructor to remain aware of the progress of the student even though the course may be entirely self-paced.
      (See Fig. 2)

```
**AIMS  REP. GEN.** REP. NO. 11** TIME 14.35.22 DATE 4/28/70 PG. NO. 1
**VOL. SUBMITTAL REVIEW** COURSE, PHYS. S211, VOL. NO. 12
-----------------------------------------------------------------------
NOTE, NO/S - SIG. THAT STUD. DID NOT SUBMIT MAT. FOR PROCESSING
      SUB. - SIG. THAT STUD. DID SUBMIT MAT. FOR PROCESSING
-----------------------------------------------------------------------
STUD. CSN PRE. STUD. STUD. STUD. STUD. STUD. ASSIGN HOME POST
          TEST GDE1  GDE2  GDE3  GDE4  GDE5         WORK TEST

 A     1  STUDENT DROPPED
 B     2  SUB. NO/S  NO/S  NO/S  NO/S  NO/S  NO/S   NO/S SUB.
 C     3  STUDENT DROPPED
 D     4  STUDENT DROPPED
 E     5  SUB. NO/S  NO/S  NO/S  NO/S  NO/S  NO/S   NO/S SUB.
 F     6  SUB. NO/S  NO/S  NO/S  NO/S  NO/S  NO/S   NO/S SUB.
 G     7  SUB. NO/S  NO/S  NO/S  NO/S  NO/S  NO/S   NO/S SUB.
 H     8  SUB. NO/S  NO/S  NO/S  NO/S  NO/S  NO/S   NO/S SUB.
 I     9  SUB. NO/S  NO/S  NO/S  NO/S  NO/S  NO/S   NO/S SUB.
 J    10  SUB. NO/S  NO/S  NO/S  NO/S  NO/S  NO/S   NO/S SUB.
```

Report No. 11     Fig. 2     Volume Submittal

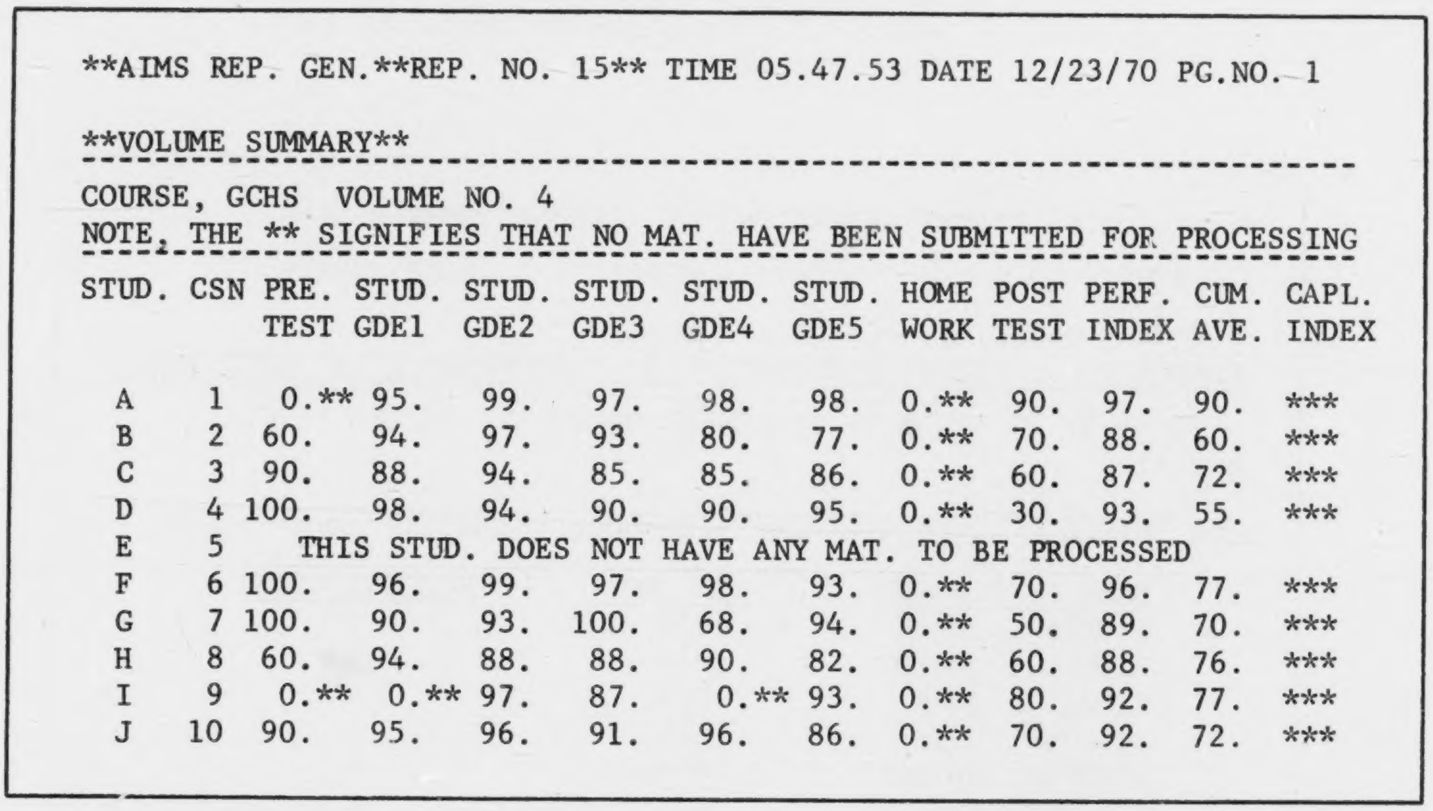
b. The instructor is also given information as to the names of those students performing below a given predetermined cut-off level on a series of behavioral objectives.

(1) This permits the instructor to schedule adequate appropriate remedial sessions with students requiring them. (See Fig. 3)

```
***A.I.M.S. REPORT GENERATOR***    REPORT NUMBER 7***
   TIME - 04.31.05     DATE - 02/06/71    PAGE NUMBER 43
TERMINAL OBJECTIVE REMEDIAL SUMMARY
LESSON 7     TERMINAL OBJECTIVE 31    COMPOSED OF 22 QUESTIONS
A TOTAL OF 19 STUDENTS PERFORMED BELOW THE CUTOFF LEVEL
SET AT 0
THE FOLLOWING STUDENTS HAVE PERFORMED BELOW THE CUTOFF LEVEL -
     NAME OF STUDENT           I.D. NO.        PERCENT ERROR
     STUDENT, LUIGI              008                 9
     STUDENT, JOSEPH             012                 9
     STUDENT, JOHN               014                 4
     STUDENT, MARK               016                13
     STUDENT, DEBORAH            019                 9
     STUDENT, LISA               020                 9
     STUDENT, ANTHONY            022                 9
     STUDENT, FREDERICK          030                 4
     STUDENT, CATHERINE          035                13
     STUDENT, RONALD             037                 4
     STUDENT, YLISA              040                 4
     STUDENT, MARIAN             042                 9
     STUDENT, NEIL               044                 9
     STUDENT, BRIAN              045                 9
     STUDENT, VINCENT            046                 4
     STUDENT, DAVID              051                68
```

Report No. 7-3          Figure 3          Class TO Performance

c. The instructor also has accessible a summary giving performance of each individual student on each volume and section of the course up to that point to which the student has progressed. (See Fig. 4)



```
**AIMS REP. GEN.**REP. NO. 15** TIME 05.47.53 DATE 12/23/70 PG.NO. 1

**VOLUME SUMMARY**
------------------------------------------------------------------
COURSE, GCHS  VOLUME NO. 4
NOTE, THE ** SIGNIFIES THAT NO MAT. HAVE BEEN SUBMITTED FOR PROCESSING
------------------------------------------------------------------
STUD. CSN PRE.  STUD. STUD. STUD. STUD. STUD. HOME POST PERF. CUM. CAPL.
          TEST  GDE1  GDE2  GDE3  GDE4  GDE5  WORK TEST INDEX AVE. INDEX

  A    1   0.** 95.   99.   97.   98.   98.   0.** 90.  97.   90.  ***
  B    2  60.   94.   97.   93.   80.   77.   0.** 70.  88.   60.  ***
  C    3  90.   88.   94.   85.   85.   86.   0.** 60.  87.   72.  ***
  D    4 100.   98.   94.   90.   90.   95.   0.** 30.  93.   55.  ***
  E    5    THIS STUD. DOES NOT HAVE ANY MAT. TO BE PROCESSED
  F    6 100.   96.   99.   97.   98.   93.   0.** 70.  96.   77.  ***
  G    7 100.   90.   93.  100.   68.   94.   0.** 50.  89.   70.  ***
  H    8  60.   94.   88.   88.   90.   82.   0.** 60.  88.   76.  ***
  I    9   0.**  0.** 97.   87.    0.** 93.   0.** 80.  92.   77.  ***
  J   10  90.   95.   96.   91.   96.   86.   0.** 70.  92.   72.  ***
```

Report No. 15 Figure 4 Volume Summary

3. FOR THE COURSE DESIGNER:

a. Reports are generated which indicate those areas of criteria design in which the criteria do not adequately evaluate the performance of the students within given behavioral objectives. (See Figs. 5 and 6)

```
           ***A.I.M.S. REPORT GENERATOR***  REPORT NO. 6
           TIME - 06.36.55  DATE - 12/04/70  PAGE NO. 1
AIMS ITEM ANALYSIS
VOLUME 2            TYPE, POST TEST          SEGMENT 1
NUMBER OF SELECTIONS PER QUESTION, 5

NUMBER OF TIMES EACH ANSWER CHOSEN
QUESTION                                          TOTAL
NUMBER        A      B      C      D      E      ANSWERS
   1          0     52*     2      1      0        55
   2          6      4      4     40*     1        55
   3         53*     0      0      1      1        55
   4          1      2      0      0     52*       55
   5          1      1     12     33*     8        55
   6          0      3     37*     0     15        55
   7          0      0      0     54*     1        55
   8         46*     6      1      0      2        55
   9          1      5     14     27      8*       55
  10          9     37*     7      1      1        55
             ---    ---    ---    ---    ---      ---
TOTAL
SELEC.       117    110     77    157     89      550
NUMBER OF WORKS PROCESSED,      55
NUMBER OF MULTIPLE SELECTIONS,   0
NUMBER OF BLANK SELECTIONS,      0
```

Report No. 6 Figure 5 Item Analysis

See: Description of this report on page 13.

Note: * indicates correct answer.

```
***A.I.M.S.    REPORT GENERATOR***  REPORT NO. 4***
TIME - 06.33.16  DATE - 12/04/70  PAGE NO. 1
AIMS HISTOGRAM ANALYSIS FOR GCHS
VOLUME, 2                TYPE, POST TEST     SEGMENT 1

22
21
20
19                                             *
18                                             *
17                                             *
16                                             *
15                                             *
14                                             *
13                                             *
12                                             *
11                                             *    *
10                                             *    *
 9                                             *    *
 8                                             *    *
 7                                   *    *    *    *
 6                                   *    *    *    *
 5                                   *    *    *    *
 4                                   *    *    *    *    *
 3                         *    *    *    *    *    *    *
 2                         *    *    *    *    *    *    *
 1                    *    *    *    *    *    *    *    *
 0---------------------------------------------------------

SCOR.   ...10   20   30   40   50   60   70   80   90   100
STUD.       0    0    1    3    3    7    7   19   11     4

NUMBER OF ZERO VALUES IN SAMPLE = 0
```

Report No. 4          Figure 6          Histogram

Note: "SCOR." indicates the possible test scores.

"STUD." indicates the number frequency of students achieving the score above.

The column to the left is the frequence scale.

## V. INPUT REQUIREMENTS

### 1. INITIAL INFORMATION INPUT

a. The AIMS III System, itself, requires certain information for input for the operation of a course. Two kinds of information are used to produce a series of background files; namely,

(1) Data regarding student background such as, age, sex, language aptitude, mathematics aptitutde, diagnostic test results and other available facts.

(2) Data regarding the course such as, question number, related objectives, correct answer choice, remedial prescriptions and other related information.

These are then used and accessed by the system during the operation of the course.

b. When a complete outline of the course in the form of behaviorable objectives, associated criteria, along with the correct responses to those criteria and related prescriptions for the student is supplied, the system is prepared to accept operational input of several types.

### 2. OPERATIONAL INPUT

This system requires control cards which indicate to it those reports which it is expected to produce and the the activities in which it is expected to engage.

a. These control cards are supplied to the system in the form of punched cards.

b. The student input information is supplied from optical scan forms which are processed through an OpScan reader onto a tape.

(1) This tape is then used as the primary input medium into the system.

### 3. OPERATION

a. The system cross checks the student's identification, the lesson number, and the type of input.

b. The system then proceeds to compare the information which was stored in the files from the beginning of the course.

c. The student's input information is filed and appropriate reports are prepared.

## VI. DESCRIPTION OF OUTPUT

1. Report number one (see Fig. 1) is the report that is given directly to the student after the test has been processed. Copies are available for distribution to the teacher, the coordinator and the student's file as required.

    a. The identifying heading which includes test number, date, student's name and number is printed for each individual student.

    b. Each question number is listed and if the student answered it correctly the letter C (correct) is noted.

    c. If the student answered the problem incorrectly, a W is noted together with a brief description of the behavioral objective.

    d. Under the heading, "MESSAGE," a remedial assignment is indicated by noting the textbook by code number and the page and problem numbers that are to be done by the student, (e.g. 597 refers to *Ninth Year Mathematics* by Dressler. 597/27.1-5 indicates that the student should do five problems on page 27 in the Dressler book.)

    e. The score on the test is listed and a personal message is printed from a predetermined set that is keyed to the test score.

2. There are no reports numbered two or three. The report numbers two and three are presently unassigned, to permit for future expansion of the system.

3. Report number four is a histogram which represents a distribution of the students correlated with the grades which they have received. (See Fig. 6)

    a. The graph represents the possible grades on the criterion evaluation along the X axis from zero to one hundred, and represents the number of students getting each possible grade along the Y axis.

4. Report number five represents a formated listing of the structure of the course for which the report is being generated. (See Fig. 7)

```
***AIMS REP. GEN. **REP. NO. 5** TIME - ZZZZZZZ DATE - ZZZZZZZ PG.NO. 1
-----------------------------------------------------------------------
COURSE STRUCTURE SUMMARY
COURSE NO. 32 COURSE NAME MATH 3012
-----------------------------------------------------------------------
VOL SEG TYP QUES TO  EO DESCRIPTION              PRESCRIPTION      ANS
 1   1   2   1   21  11 3045 GCF                 50/91-1,2,5,7,8    B
 1   1   2   2   21  12 3066 LCM                 50/254-1-9         A
 1   1   2   3   11  11 3055 NUMS                40/221-1-3         D
 1   1   2   4   11  12 3056 DENS                30/192-1-5         C
 1   1   2   5   12  21 3043 ORDER LIKE FRACT    30/186-1-4         D
 1   1   2   6   12  23 3078 ORDER UNLIKE FRACT  40/149-1-5         C
 1   1   2   7   12  22 3044 ORDER LIKE FRACT    30/187-1-4         A
 1   1   2   8   21  14 3048 MULT BY ONE         50/218-1-6         C
 1   1   2   9   21  17 3051 LOWEST TERMS        50/214-1-5         C
 1   1   2  10   22  23 3083 ADD LIKE FRACT      40/219-1-3         E
```

Report No. 5 Figure 7 Course Structure

Note: VOL: STUDY GUIDE VOLUME NUMBER
SEG: STUDY GUIDE SEGMENT NUMBER
TYP: TYPE 2 is a POST TEST

5. Report number six lists by question the number of students who chose each of the possible selections on a criterion evaluation. (See Fig. 5)

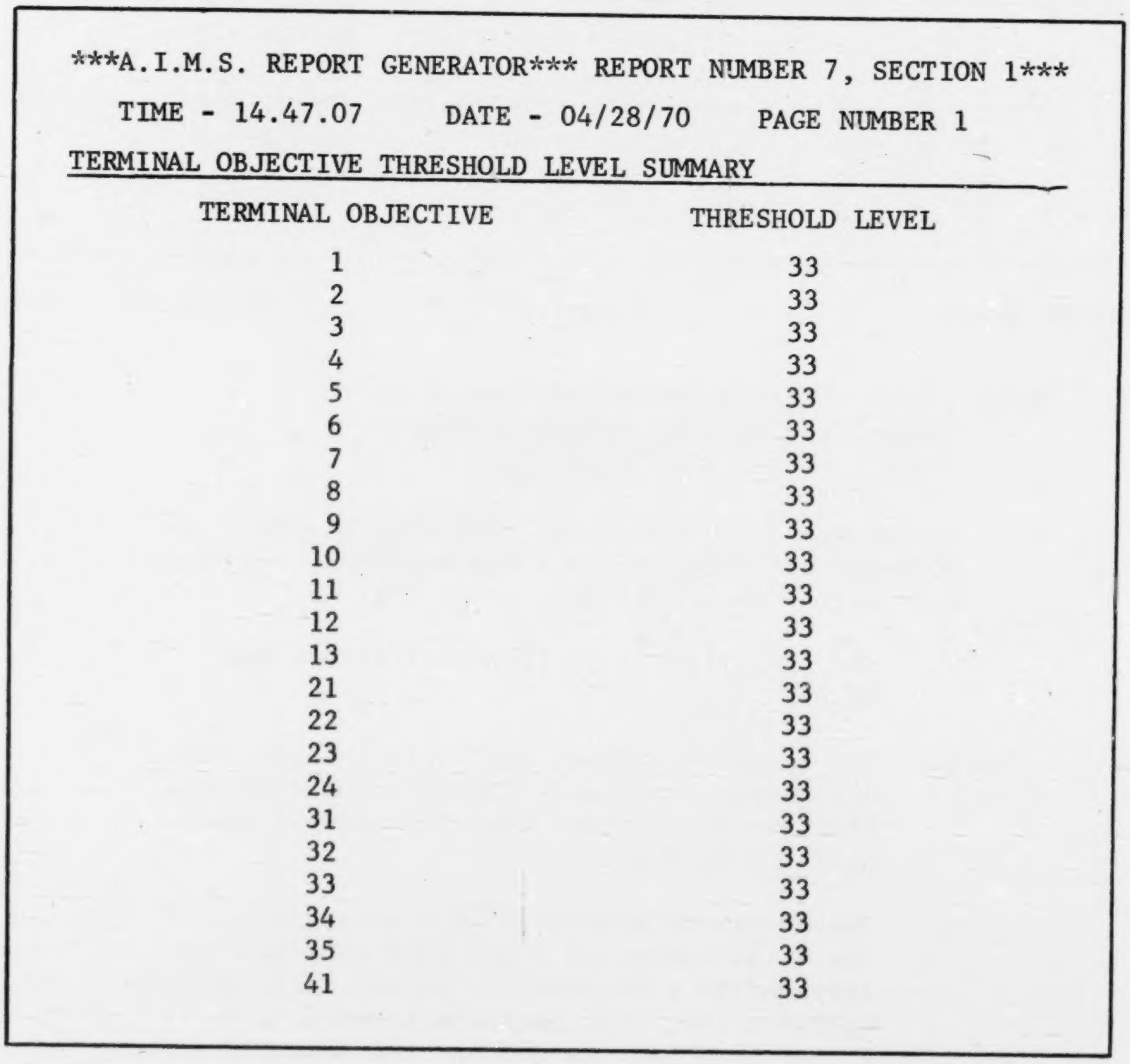
   a. This function is an item analysis of that test.

   b. The question numbers available on that test are listed vertically and on the horizontal axis are the various possible answers available for each question.

   c. The matrix is completed by a presentation of the total number of times each question was answered by each possible answer. For example, question one, with possible answers A, B. C. D, may have had one student who answered the question with A, four students who answered the question with B, and seven students who answered the question with C. These will be printed on the matrix. In addition, the correct answer for each question is starred with an asterisk.

d. The primary function of this report is to supply information to the course designer as to the adequacy of the criteria and their relationship to the behavioral objectives with which they are concerned.

6. Report number seven consists of five sections which contain information useful to all three target groups. All 5 sections are distributed to course instructors and designers. Only section 1 is distributed to students. Section 2 is given only to the student whose name appears on it.
(See: Figs. 8-12 following)



```
***A.I.M.S. REPORT GENERATOR*** REPORT NUMBER 7, SECTION 1***
   TIME - 14.47.07      DATE - 04/28/70     PAGE NUMBER 1
TERMINAL OBJECTIVE THRESHOLD LEVEL SUMMARY
        TERMINAL OBJECTIVE               THRESHOLD LEVEL
                 1                             33
                 2                             33
                 3                             33
                 4                             33
                 5                             33
                 6                             33
                 7                             33
                 8                             33
                 9                             33
                10                             33
                11                             33
                12                             33
                13                             33
                21                             33
                22                             33
                23                             33
                24                             33
                31                             33
                32                             33
                33                             33
                34                             33
                35                             33
                41                             33
```

Report No. 7-1 Figure 8 TO Cutoff Level

a. Section One of this report is a listing of objectives with their related threshold levels.

   The threshold level, or cutoff level, is the percent of failure in answering the questions that is tolerated.

   If a student's failure rate is greater than the level indicated he will be listed in the other parts of report seven as being in need of additional remedial work.

b. Section Number Two is a separate listing of each student who has incorrectly answered the question relating to an objective, to a degree greater than the tolerated threshold level specified. It lists each objective and the student's performance expressed as a percent of error.

   (1) This supplies information to the instructor as to the overall performance and the performance on specific objectives for each individual student.

   (2) As this report is currently designed, if a student performs below the cut-off level on any given objective, his performance on all the associated objectives is listed out. If a student performs above the cut-off level on all objectives, he is not listed at all in this section of the report.

   (3) The objective of this is to pick up the student who is weak in an area and may only fall below the cut-off level on one or two objectives. However, it is often desirable for the instructor to be made aware of the student's performance on associated objectives, thus, this report section. (See Figure 9)

```
***A.I.M.S. REPORT GENERATOR***  REPORT NUMBER 7, SECTION 2***
   TIME - 14.47.57   DATE - 04/28/70    PAGE NUMBER 2
STUDENT, IRA, JR.       I. D. NUMBER 577685690
THE STUDENT IDENTIFIED ABOVE HAS PERFORMED BELOW PRE-SET LEVELS
OF PERFORMANCE ON TERMINAL OBJECTIVES IN LESSON 1
--------------------------------------------------------------
                           PERFORMANCE DATA
T.O.                     PERCENT ERROR          CUTOFF LEVEL
 21                            8                     33
 22                            8                     33
 33                           14                     33
 41                           10                     33
 43                            8                     33
 51                           27                     33
 52                           50                     33
```

Report No. 7-2          Fig. 9          Student TO Performance

c. Section Three is a report for each objective, which lists the objective number, the number of questions relating to that objective, the number of students who performed below the cut-off level and the cut-off level for that objective.

   (1) In addition, the name of the student is listed with the percentage error which that student achieved.

```
***A.I.M.S. REPORT GENERATOR  REPORT NUMBER 7, SECTION 3***
   TIME - 14.48.11     DATE - 04/28/70     PAGE NUMBER 3
TERMINAL OBJECTIVE REMEDIAL SUMMARY
-----------------------------------------------------------
LESSON 1         TERMINAL OBJECTIVE 52   COMPOSED OF 4 QUES.
A TOTAL OF  1  STUDENTS PERFORMED BELOW THE CUTOFF LEVEL
SET AT 33
-----------------------------------------------------------
THE FOLLOWING STUDENTS HAVE PERFORMED BELOW THE CUTOFF LEVEL
      NAME OF STUDENT       I. D. NO.     PERCENT ERROR
      STUDENT, IRA, JR.     577685690          50
```

Report No. 7-3          Fig. 10          Class TO Performance

d. Sections Four and Five relate to the scheduling of remedial sessions for students who performed below cut-off level within this lesson (See Fig. 11)

```
***A.I.M.S. REPORT GENERATOR  REPORT NUMBER 7, SECTION 4***
   TIME - 14.48.29     DATE - 04/28/70     PAGE NUMBER 1
REMEDIAL SESSION - LESSON PLAN - LESSON 1
-------------------------------------------------------------
SESSION 1        PROF. AND/OR LOCATION    PROF. SMITH  RM 100
-------------------------------------------------------------
     TERMINAL OBJECTIVES       CUTOFF LEVEL   NO. OF STUDENTS
            52                      33               1
```

Report No. 7-4 Fig. 11 TO Remedial Lesson Plan

(1) The students are assigned to a remedial session based upon that objective with which they had the most difficulty. A listing of objectives to be covered, the associated cut-off level, and the number of students who performed below the cut-off level is provided. (See Fig. 12)

```
***A.I.M.S. REPORT GENERATOR  REPORT NUMBER 7, SECTION 5***
  TIME - 15.34.02       DATE - 11/24/69    PAGE NUMBER 4
REMEDIAL SESSION ROSTER       LESSON 11       SESSION 4
------------------------------------------------------------
PROF AND/OR LOCATION - PROFESSOR SURACI          ROOM 209
------------------------------------------------------------
                                    TERMINAL OBJECTIVES
                              ------------------------------

TERMINAL OBJECTIVE NUMBERS    82

THRESHOLD LEVELS SET AT       33

THE FOLLOWING STUDENTS HAVE BEEN ASSIGNED TO THIS REMEDIAL SESS.
----------------------------------------------------------------

        STUDENT NAME                 I.D. NO.    PERCENTAGE ERROR

        STUDENT, ROD C.                 85              50
        STUDENT, MIKE M.                91              50
        STUDENT, RANDALL L.             97              66
        STUDENT, FRED A.               101              66
        STUDENT, THOMAS C.             102              50
        STUDENT, RONALD A.             113              66
        STUDENT, JOHN J.               114              50
        STUDENT, JOHN F.               137              66
        STUDENT, GARY G.               138              50
        STUDENT, PAUL H.               147              50
        STUDENT, ROBERT H.             170              50
        STUDENT, PETER K.              180              66
        STUDENT, RUSS C.                20              33
        STUDENT, JOHN A.                26              83
```

Report No. 7-5          Fig. 12   Assignment to Remedial Sessions

7. Reports Eight, Nine, and Ten have not been assigned, to permit future report expansion.

8. Report Number Eleven is used for determining the rate with which students are progressing through the course. (See Fig. 2)

   a. This report indicates, by student, which students have and which students have not submitted materials for various sections of the course.

9. Report number twelve is a roster of the students within the class. (See Fig 13)

```
**AIMS REP. GEN. ** REP. NO. 12**
TIME - 14.39.44   DATE - 04/28/70  PAGE NUMBER 1
-------------------------------------------------------------
**CLASS ROSTER**
COURSE, PHYSICS S211
-------------------------------------------------------------

     STUDENT                ACADEMY             COURSE
                              NO.                 NO.

     STUDENT A               0266                  1
     STUDENT B               1029                  2
     STUDENT C               1358                  3
     STUDENT D               1449                  4
     STUDENT E               1694                  5
     STUDENT F               1799                  6
     STUDENT G               1932                  7
     STUDENT H               2079                  8
     STUDENT I               2380                  9
     STUDENT J               2702                 10
     STUDENT K               4165                 11
     STUDENT L               4571                 12
```

Report No. 12 Fig. 13 Class Roster

Note: The class roster can be augmented to include any data desired such as: instructor's name, room number, and day and time of class sessions.

10. Reports Thirteen (Fig 14) and Fourteen (Fig 15) have been designed to provide group statistics for a specific course, and require very specific background information and course design in order to be used for courses other than the one specified.

    a. These two reports were designed to establish a quantitative measure of the capabilities and performances of the students in Physics 4001 (Articulated Multimedia Physics) both individually and as a group.

    b. Printout Thirteen presents the minimum, maximum and mean indices for the class as one group derived from the individual indices of the members of the class.

    c. Printout Fourteen presents the indices for each individual student.

```
**AIMS REP. GEN. ** REP. NO. 13**
TIME - 12.01.34  DATE - 04/07/70  PG. NO. 1
------------------------------------------------
** VOLUME STATISTICS **
COURSE, PHYSICS 4001       VOLUME NO. 2
------------------------------------------------

                            MIN.    MEAN.    MAX.
CAPABILITY INDEX             47      65      106
PERFORMANCE INDEX            70      78       85
PERFORMANCE DEVIATION                13
PROBLEM ACHIEVEMENT          18      31       45
POST TEST ACHIEVEMENT        30      54       70
NET ACHIEVEMENT INDEX                55
ACHIEVEMENT DEVIATION               -10
```

Report No. 13 Fig. 14 General Volume Statistics

11. Report Fifteen represents a summary of the performance of all students in a class on the components of one volume (or lesson). (See Fig. 4)

12. Report Sixteen is an alternate form of Report Fifteen. Report Fifteen lists the entire roster of all students taking the course in one alphabetical order, whereas, Report Sixteen lists each separate class in alphabetical order. This is done to aid the class instructors in locating the records of their own students.

```
***A.I.M.S. REPORT GENERATOR*** REPORT NUMBER 14***
TIME - 12.01.36  DATE - 04/07/70   PAGE NUMBER 1

------------------------------------------------------------------------------------------------

***INDIVIDUAL VOLUME STATISTICS***  COURSE, PHYSICS 4001   VOLUME NO. 2

------------------------------------------------------------------------------------------------

                                ABS.   REL.          POST          ABS.  REL.  CMAV   CMAV   CMAV  CMAV
                   CAPB.  PERF. PERF.  PERF.  PROB.  TEST   NET    ACH.  ACH.  PROB.  PT.T   NET   REL.
STUDENT       CSN  IND.   IND.  DEV.   DEV.   ACH.   ACH.   ACH.   DEV.  DEV.  ACH.   ACH.   ACH.  ACH.DEV.

STUDENT A      1   47.    70.   23.    10.    34.    30.    52.     5.   15.  34.    30.    52.    15.
STUDENT B      2      THIS STUDENT HAS INSUFFICIENT MATERIALS TO BE PROCESSED
STUDENT C      3   64.    79.   15.     2.    45.    60.    62.    -2.    8.  45.    60.    62.     8.
STUDENT D      4   63.    85.   22.     9.    24.    40.    54.    -9.    1.  24.    40.    54.     1.
STUDENT E      5   53.    82.   29.    16.    37.    70.    59.     6.   16.  37.    70.    59.    16.
STUDENT F      6   76.    78.    2.   -11.    25.    50.    51.   -25.  -15.  34.    55.    57.    11.
STUDENT G      7   51.    75.   24.    11.    18.    60.    46.    -5.    5.  18.    60.    46.     5.
STUDENT H      8  106.    82.  -24.   -37.    40.    70.    61.   -45.  -35.  42.    65.    64.   -12.
```

Report No. 14 Fig. 15 Individual Statistical Volume Summary

## VII. THE CURRENT STATUS OF OPERATIONS OF AIMS III

### 1. INSTALLATIONS

AIMS III is currently operating at several locations The major example is New York Institute of Technology, both Old Westbury and Manhattan campuses. The courses being used are specifically designed to use the Computer Management System.

a. The mathematics course is also functioning at Glen Cove High School (GCHS).

b. Another set of learning materials prepared by the staff of Mineola Junior High School is being designed for use with the Computer Management System.

c. The Self-Paced Multimedia Physics program installed at the United States Naval Academy is designed for use with the Computer Management System.

### 2. DESIGN

The Instructional Management System was originally designed to operate on an IBM 360/30 operating under DOS. It has also been adapted so as to be operational under OS on the IBM 360/65. However, since it is largely written in FORTRAN it is readily adaptable to other manufacturers' computers.

a. INPUT

The system as currently run has three types of input.

(1) Data concerning the behavioral objectives,

(2) remediation, and

(3) prescriptions appropriate to a given course.

b. The AIMS System also provides a computer operating format sufficient to carry out the research relating to individualization and optimization of instruction. This is exemplified in the project "Research Study of Individual Learning Characteristics."

## 3. OPERATIONAL GOALS

a. The AIMS III System had three operational goals:

   (1) To provide feedback to the student with appropriate reinforcement and remediation;

   (2) To provide information to the instructor and/or the course designer for course evaluation; and

   (3) To provide a periodic summary of student performance.

b. The first area of consideration, a provision for immediate feedback to the student of his performance with appropriate remediation measures, was obviously under rigid time constraints.

   (1) The most voluminous output is generated in this area of system performance.

   (2) Some difficulty had been experienced in meeting the instructor's requirement for a quick turnaround of input material to finished printout. This requirement for fast processing was necessary when performance on a Pretest determined whether the student was exempt from the remainder of the lesson (volume) or whether he was required to proceed through the lesson. In this instance, the feedback information needed to be supplied almost instantly.

   (3) In cases where the student was to be supplied additional remedial instruction because of a poor performance on a Posttest, the information had to be in his hands within twenty-four hours.

   The operational problems presented by these requirements were examined and solved by the New York Institute of Technology Systems Design Group.

c. The reports generated by the system to meet the other goals, namely, course evaluation, course optimization and evaluation of general class performance, did not need immediate printout reports.

(1) Various users indicated that the requirements for the production of summary reports rarely required a turnaround time of less than forty-eight hours. Frequently, longer delays were acceptable.

## VIII. CONCLUSION

The variety of reports generated by the AIMS III program enables the course writers and instructors to determine the answer to two questions.

1. Does the teaching program present the concepts in a satisfactory manner that facilitates the learning of the students?
2. Does the testing program adequately measure the performance of a student in demonstrating his achievement of a specific behavioral objective?

The AIMS III System permits the course designer to construct and implement a multibranched course in a self-paced environment. At the same time, it provides the instructor with the tools necessary to permit him to function in a consultative role with the students, rather than being hampered by the need to function in a clerical role.

Since the completion of AIMS III, development of the system has continued with the attendant expenses borne by the Institute. AIMS IV incorporates a predictor function whereby student performance is projected at each stage on the basis of performance in preceding stages. This feature is addressed in the sections which follow.

## IX. DEVELOPMENT OF PREDICTOR EQUATIONS

The Simulator is designed to operate in a modular structured course environment where each student's performance is measured at the end of a module and combined with background data to predict the student's performance for the next stage. A course is viewed as a string of modules or stages and the prediction equations are developed assuming that the student has completed the $i^{th}$ stage and is entering the i + 1 stage.

Let $\underline{y}_i$ be a vector that represents the student's performance and $\underline{p}_i$ be a vector that denotes the student's backbround data at the end of the $i^{th}$ stage. The background data can be constant throughout the course or include past course history (i.e., measurements of performance at stage i - 1). The order and format of the background and performance vectors are fixed for each stage of the course. For example, if post test scores and achievement test grades are the measurements of interest, $\underline{y}_i$ is a 2 × 1 vector and the post test scores and achievement test grades must be measured at the conclusion of each stage. Here it will be assumed that there are n measurements and s background variables. Thus, $\underline{y}_i$ is a n × 1 vector and $\underline{p}_i$ is a s × 1 vector.

The basic philosophy of the Simulator is stated as follows: If the student background data is known at the output of the $i^{th}$ stage, then there exists a functional relationship such that

$$\underline{y}_{i+1} = \underline{g}_i(\underline{p}_i) \qquad (1)$$

Equation (1) says that the student performance at the i + 1 module is a function of the background data at the $i^{th}$ stage. The functional relationship $\underline{g}_i$ is unknown, however, if the background data has significant correlation with the measured performance, a linear relationship can be assumed, namely,

$$\underline{y}_{i+1} = J_i\,\underline{p}_i + \underline{c}_i \qquad (2)$$

where

$\underline{y}_{i+1}$ - n × 1 vector

$\underline{p}_i$ - s × 1 vector

$J_i$ - n × s matrix

$\underline{c}_i$ - n × 1 vector

and the elements of $J_i$ and the vector $\underline{c}_i$ are unknown.

Examining Equation 2, the problem of estimating the performance at stage i + 1 (i.e., $\underline{y}_{i+1}$) reduces to determining the unknown elements of the matrix $J_i$ and the vector $\underline{c}_i$.

Before proceeding, it is convenient to represent Equation 2 in a simpler format. Let $(\underline{a}^T{}_k)_i$ be the k^th^ row of the matrix $J_i$, namely

$$(a^T{}_k)_i = [a_{k1} a_{k2} \cdot \cdot \cdot a_{ks}]_i \qquad (3)$$

In view of Equation 3, $J_i$ is written as

$$J_i = \begin{vmatrix} \underline{a}_1 T \\ \underline{a}_2 T \\ \cdot \\ \cdot \\ \cdot \\ \underline{a}_n T \end{vmatrix}_i \qquad (4)$$

$$(n \times s \text{ matrix})$$

Using Equation 4, the product $J_i \, \underline{p}_i$ can be written as

$$J_i \, \underline{p}_i = \begin{vmatrix} \underline{a}_1 T \, \underline{p}_i \\ \underline{a}_2 T \, \underline{p}_i \\ \cdot \\ \cdot \\ \cdot \\ \underline{a}_n T \, p_i \end{vmatrix} = \underset{n \times (n*s)}{\begin{vmatrix} \underline{p}_i T & o & o \\ o & \underline{p}_i & o \\ & & \\ o & & \underline{p}_i T \end{vmatrix}} \; \underset{(n*s) \times 1}{\begin{vmatrix} \underline{a}_1 \\ \underline{a}_2 \\ \cdot \\ \cdot \\ \cdot \\ \underline{a}_n \end{vmatrix}_i} \qquad (5)$$

where

$a_k$ - s × 1 vector

Defining the matrix $\tilde{M}_i$ as

$$\tilde{M}_i = \begin{vmatrix} \underline{p}_i T & o & o \\ o & & \underline{p}_i T \end{vmatrix} \quad n \times (n*s)$$

and the vector $\tilde{\underline{x}}_i$ as

$$\tilde{\underline{x}}_i = \begin{vmatrix} \underline{a}_1 \\ \underline{a}_2 \\ \cdot \\ \cdot \\ \cdot \\ \underline{a}_n \end{vmatrix} \quad (n*s) \times 1$$

Equation 2 is written as

$$\underline{y}_{i+1} = \tilde{M}_i \, \tilde{\underline{x}}_i + \underline{c}_i \qquad (6)$$

From Equation 6 it is seen that the unknown are the components of the vector $\tilde{\underline{x}}_i$ and the vector $\underline{c}_i$. Combining $\tilde{\underline{x}}_i$ and $\underline{c}_i$ in one unknown vector $\tilde{\underline{x}}_i$ as

$$\underline{x}_i = \left| \begin{array}{c} \tilde{\underline{x}}_i \\ --- \\ \underline{c}_i \end{array} \right| \quad (n*s+n) \times 1$$

Equation 6 is expressed as

$$\underline{y}_{i+1} = M_i \, \underline{x}_i \qquad (7)$$

where

$$M_i = [\tilde{M}_i \quad I_n] \text{ -nx}(n*s+n) \quad \text{matrix}$$

and

$$I_n \text{ - } n \times n \quad \text{Identity matrix}$$

Let $m = n*s+n$. Thus, $M_i$ is a $n \times m$ matrix and $\underline{x}_i$ is a $m \times 1$ vector. Equation 7 is the form of the model that is subsequently utilized where the vector $\underline{x}_i(m \times 1)$ is referred to as the state vector and $M_i$ is a known matrix that relates the state to the performance vector.

In order to compute the "best" estimate of the performance at stage i + 1, one must consider what is known at stage i. It is assumed that at stage i a measurement of the student's performance denoted as $\overset{o}{\underline{y}}_i$, is available along with an estimate of the state referred to as $\hat{\underline{x}}_i$. It would be desirable, of course, to have a measurement of performance for stage i + 1 (i.e., $\overset{o}{\underline{y}}_{i+1}$), but since the prediction is being made for stage i + 1, the best that can be done with the existing information is to let $\overset{o}{\underline{y}}_{i+1} = \overset{o}{\underline{y}}_i$. In addition to the measurements and the state estimates, the errors in the measurements and the estimates of the state must be quantified. Let the error between the "true" state and the estimate of the state (at stage i) be defined as

$$\underline{\Delta x}_i = \hat{x}_i - x_i \text{ (error in state at stage i)} \qquad (8)$$

and the error between the measurement and the "true" performance vector (at stage i + 1) denoted as

$$\underline{\Delta y}_i = \overset{o}{\underline{y}}_{i+1} - \underline{y}_{i+1} = \overset{o}{\underline{y}}_i - \underline{y}_{i+1} \text{ (error in measurement at stage i + 1)} \qquad (9)$$

Note $\underline{\Delta x}_i$ is a m × 1 vector and $\underline{\Delta y}_i$ is a n × 1 vector.

Combining the error vectors in Equations 8 and 9 into a (n+m) × 1 vector expressed as

$$\underline{\Delta e}_i = \begin{vmatrix} \underline{\Delta x}_i \\ --- \\ \underline{\Delta y}_i \end{vmatrix} \quad -(n+m) \times 1 \text{ vector} \qquad (10)$$

a covariance matrix $P_i$ (n+m × n+m) can be defined as follows:

$$P_i = E[\underline{\Delta e}_i \; \underline{\Delta e}_i^T] = \begin{vmatrix} A_i & D_i \\ D_i^T & B_i \end{vmatrix} \qquad (11)$$

where

$$A_i = E[\underline{\Delta x}_i \; \underline{\Delta x}_i^T] \; - \; m \times m \text{ matrix}$$

$$B_i = E[\underline{\Delta y}_i \; \underline{\Delta y}_i^T] \; - \; n \times n \text{ matrix}$$

$$D_i = E[\underline{\Delta x}_i \; \underline{\Delta y}_i^T] \; - \; n \times m \text{ matrix}$$

and E is the expected operator notation.

Thus, in addition to knowing the measurement vector $\overset{o}{\underline{y}}_i$ and an estimate of the state vector $\hat{\underline{x}}_i$, it is also assumed that an estimate of the covariance matrix $P_i$ is known at stage i.

Before continuing into the details of the mathematics, consider what is to be ascertained. Since it is assumed that an estimate of the state $\hat{\underline{x}}_i$, is known at stage 1, a prediction for the performance at stage i + 1 denoted as $\hat{\underline{y}}_{i+1}$ can be made from Equation 7 (i.e., $\underline{y}_{i+1} = M_i \; \hat{\underline{x}}_i$). In view of the previous discussion, however, it is apparent that the knowledge of the measurement ($\overset{o}{\underline{y}}_i$) and the covariance matrix ($P_i$) is not used in the prediction.

If Equation 8 is examined, it is desirable to use this information to find $\underline{\Delta x}_i$ from which the true state is readily determined and the prediction is computed from Equation 7. This is not possible since $\underline{\Delta x}_i$ is a random quantity. However, the information can be utilized to find an "optimal" estimate of $\underline{\Delta x}_i$, denoted as $\hat{\underline{\Delta x}}_i$, that minimizes the probability of error. Mathematically this equivalent to finding the error vector $\underline{\Delta e}_i$ (Equation 10) that maximizes the likelyhood function of the errors, namely

$$L_i = k \; \text{EXP}(- \tfrac{1}{2} \; \underline{\Delta e}_i^T \; P_i^{-1} \; \underline{\Delta e}_i) \qquad (12)$$

where k is a constant such that the integration $L_i$ over m + n space is unity.

Let $R_i = \frac{1}{2}\,\underline{\Delta e}_i^T\, P_i^{-1}\, \underline{\Delta e}_i$ then maximizing $L_i$ is equivalent to minimizing $R_i$. In order to minimize $R_i$, one must consider the independent components of $\underline{\Delta e}_i$. Examining Equations 7, 8, and 9 it is seen that $\underline{\Delta y}_i$ is a function of $\underline{\Delta x}_i$, namely

$$\underline{\Delta y}_i = \overset{o}{\underline{y}}_i - \underline{y}_{i+1} = \overset{o}{\underline{y}}_i - M_i\underline{x}_i = \overset{o}{\underline{y}}_i - M_i\underline{\hat{x}}_i + M_i\underline{\Delta x}_i \qquad (13)$$

Thus, $\underline{\Delta e}_i$ (and $R_i$) is a function of the components of $\underline{\Delta x}_i$ (m independent variables), where $\Delta x_{ki}$ is the $k^{th}$ component of $\underline{\Delta x}_i$, and minimizing $R_i$ requires the components of $\underline{\Delta x}_i$ to satisfy the following set of equations:

$$\frac{\partial R_i}{\partial \Delta x_{ki}} = 0 \qquad k - 1, \ldots, m \qquad (14)$$

Performing the differentiation in Equation 13 yields the following:

$$\frac{\partial R_i}{\partial \Delta x_{ki}} = \frac{\partial \underline{\Delta e}_i^T}{\partial \Delta x_{ki}}\, P_i^{-1}\, \underline{\Delta e}_i = 0 \qquad (15)$$

for

$$k = 1, 2, \ldots, m$$

but

$$\frac{\partial \underline{\Delta e}_i}{\partial \Delta x_{ki}} = \left|\begin{array}{c} \underline{1k} \\ \hline M_i\underline{1}_k \end{array}\right| = \left|\begin{array}{c} I_m \\ \hline M_i \end{array}\right| \underline{1}_k \qquad (16)$$

where $I_m$ - m × m identity matrix

$M_i$ - n × m matrix defined in Equation 7

$1_k$ - m × 1 vector filled with zeros except for the $k^{th}$ component which is 1 (one).

From Equations 14, 15, and 16, the equations in 14 reduce to

$$[I_m\ M_i^T]\, P_i^{-1}\ \underline{\Delta e}_i = 0 \qquad (17)$$

Noting the dependency of $\underline{\Delta y}_i$ on $\underline{\Delta x}_i$ from Equation 13 and defining $\overset{o}{y}_i - M_i\underline{\hat{x}}_i = r_i$ (known vector) and $N_i = \left|\begin{array}{c} I_m \\ \hline M_i \end{array}\right|$ (m+n) × m matrix, $\underline{\Delta e}_i$ is written as

$$\underline{\Delta e}_i = \left|\begin{array}{c} \underline{\Delta x}_i \\ \hline \underline{r}_i + M_i\underline{\Delta x}_i \end{array}\right| = \left|\begin{array}{c} 0 \\ \hline r_i \end{array}\right| + \left|\begin{array}{c} I_m \\ \hline M_i \end{array}\right| \underline{\Delta x}_i = \left|\begin{array}{c} 0 \\ \hline r_i \end{array}\right| + N_i\ \underline{\Delta x}_i \qquad (18)$$

Substituting Equation 18 into Equation 17 yields the following:

$$N_i^T P_i^{-1} \left|\begin{array}{c} 0 \\ \hline \underline{r_i} \end{array}\right| + N_i^T P_i^{-1} N_i \underline{\Delta x_i} = 0$$

$$\begin{aligned} N_i^T P_i^{-1} N_i \underline{\Delta x_i} = -N_i^T P_i^{-1} \left|\begin{array}{c} 0 \\ \hline \underline{r_i} \end{array}\right| &= -N_i^T P_i^{-1} \left|\begin{array}{c} 0 \\ \hline I_n \end{array}\right| \underline{r_i} \\ &= -N_i^T P_i^{-1} Z\underline{r_i} \end{aligned} \tag{19}$$

where

$$Z = \left|\begin{array}{c} 0 \\ \hline I_n \end{array}\right|$$

From Equation 19, the optimal estimate of $\underline{\Delta x_i}$ is determined as

$$\underline{\hat{\Delta} x_i} = -(N_i^T P_i^{-1} N_i)^{-1} N_i^T P_i^{-1} Z\underline{r_i} \tag{20}$$

Substituting Equation 20 into Equation 18 yields the optimal estimate of $\underline{\Delta e_i}$, namely

$$\underline{\Delta e_i} = \left|\begin{array}{c} \underline{\hat{\Delta} x_i} \\ \hline \underline{r_i} + M_i \underline{\hat{\Delta} x_i} \end{array}\right| = \left|\begin{array}{c} -(N_i^T P_i^{-1} N_i^T)^{-1} N_i^T P_i^{-1} Z \\ \hline I_n - M_i (N_i^T P_i^{-1} N_i)^{-1} N_i^T P_i^{-1} Z \end{array}\right| \underline{r_i} \tag{21}$$

Let

$$K_i = \left|\begin{array}{c} -(N_i^T P_i^{-1} N_i)^{-1} N_i^T P_i^{-1} Z \\ \hline I_n - M_i (N_i^T P_i^{-1} N_i)^{-1} N_i^T P_i^{-1} Z \end{array}\right|$$

thus

$$\underline{\hat{\Delta} e_i} = K_i \underline{r_i} \tag{22}$$

It can be shown that $K_i$ can be expressed in simpler form, namely

$$K_i = P_i H_i^T (H_i P_i H_i^T)^{-1} \tag{23}$$

To summarize, the matrix $M_i$ and the vectors $\underline{\hat{x}_i}$ and $\underline{\overset{o}{y}_i}$ are known along with the covariance matrix $P_i$. The vector $\underline{r_i}$ is computed from the equation $\underline{r_i} = \underline{\overset{o}{y}_i} - M\underline{\hat{x}_i}$ and the matrix $K_i$ is determined from Equation 23. From Equation 22, the optimal estimate of the error vector is found. The first m components, (Equation 10) $\underline{\hat{\Delta} x_i}$ is the optimal estimate of the state error defined in Equation 8. From Equation 8 it is seen that the new estimate of the state, denoted as $\underline{\overset{*}{x}_i}$, is computed as

$$\underline{\overset{*}{x}_i} = \underline{\hat{x}_i} - \underline{\hat{\Delta} x_i} \tag{24}$$

The prediction for stage i + 1, denoted as $\underline{\overset{*}{y}_{i+1}}$, is determined from Equation 7 as

$$\underline{\overset{*}{y}_{i+1}} = M_i \underline{\overset{*}{x}_i} \tag{25}$$

When new information is processed, the procedure is repeated. Successively, better estimates can be obtained from the information being processed if the covariance matrix $P_i$ is updated at each stage. This can be done utilizing the following equation

$$P_{i+1} = P_i - K_i H_i P_i \tag{26}$$

where $P_{i+1}$ is the updated covariance matrix. The iterative procedure obtains the measured data, determines the error vector, makes the prediction for the next stage and then updates the covariance matrix. In order to implement the procedure, an initial estimate of the state ($\hat{\underline{x}}o$) and the covariance matrix Po is required. It will be shown in the document for the initial estimator (Item 5) how to provide these estimates.

# X. SIMULATION OF LOGIC

The purpose of this document is to define the simulation logic and specify the programming requirements for the AIMS Simulator. The data I/O routines required to access the Simulator are described in general terms in the logic structure of the Simulator. The explicit specifications of the I/O routines are course dependent and must be defined by the user.

## 1. MODEL STRUCTURE

The description of the general data format is discussed in Item 1 ("Course Structure Definition for the AIMS Simulator"). To facilitate the programming requirements, the following quantities are defined:

a. n - The number of student performance indices measured at *each* stage of the course.

b. s - The number of background (predictor) variables being used in the model.

c. $\underline{y}_i$ - The student's performance vector at stage i. (n × 1)

d. $\underline{p}_i$ - The student's background vector at stage i. (s × 1)

e. m - $n*s+n$

The student's performance at stage i+1 is related to the predictor variables by the following model:

$$\underline{y}_{i+1} = J_i \underline{p}_i + \underline{c}_i \qquad (1)$$

where

$\underline{c}_i$ - an unknown vector n × 1

$J_i$ - n × s matrix of unknown coefficients

The model in Equation 1 is rewritten as

$$\underline{y}_{i+1} = M_i \, \underline{x}_i \qquad (2)$$

where

$\underline{x}_i$ - an unknown vector (m × 1) consisting of all the coefficients of the matrix $J_i$ and the vector $\underline{c}_i$.

$M_i$ - n × m matrix defined as

$$M_i = \left|\begin{array}{ccccc|c} \underline{p}_i^T & \tilde{0} & \tilde{0} & \ldots & \tilde{0} & 10\ldots0 \\ & \underline{p}_i^r & \tilde{0} & \ldots & \tilde{0} & 01\ldots0 \\ \tilde{0} & & & & \underline{p}_i^T & \underbrace{0 \quad 1}_{I_n} \end{array}\right| \quad n \times (n_*s+n) \qquad (3)$$

$\tilde{0}$ - 1 × s Row of Zeros

## XI. DOCUMENTATION AVAILABILITY

The following additional materials and services are available from:

New York Institute of Technology
Wheatley Road
Old Westbury, New York 11568

1. AIMS Program Logic Manual
2. Computer tape of AIMS System (9 track, 800 or 1600 BPI)
3. Implementation advice and assistance
4. Course interpreting and systems design information
5. Technical assistance for user personnel

## APPENDIX

The following are representative charts which depict the broad logic of AIMS III:

| Chart Number | Title | Page |
|---|---|---|
| 1 | AIMS III Phase Structure | 35 |
| 2 | AIMS III System Structure | 36 |
| 3 | Course Structure | 37 |
| 4 | AIMS III Program Structure | 38 |
| 5 | Creating a Student Background File | 39 |
| 6 | Student Background and Enrollment | 40 |
| 7 | Course Description | 41 |
| 8 | Header File | 42 |
| 9 | File Maintenance and Updating | 43 |
| 10 | Student Response Tape | 44 |
| 11 | Master Response Tape | 45 |
| 12 | Question (MBO) File | 46 |
| 13 | Report Generation | 47 |
| 14 | Monitoring of Individual and Group Performance | 48 |
| 15 | System Logic-GRI Module | 49 |

Chart 1

# AIMS III PHASE STRUCTURE

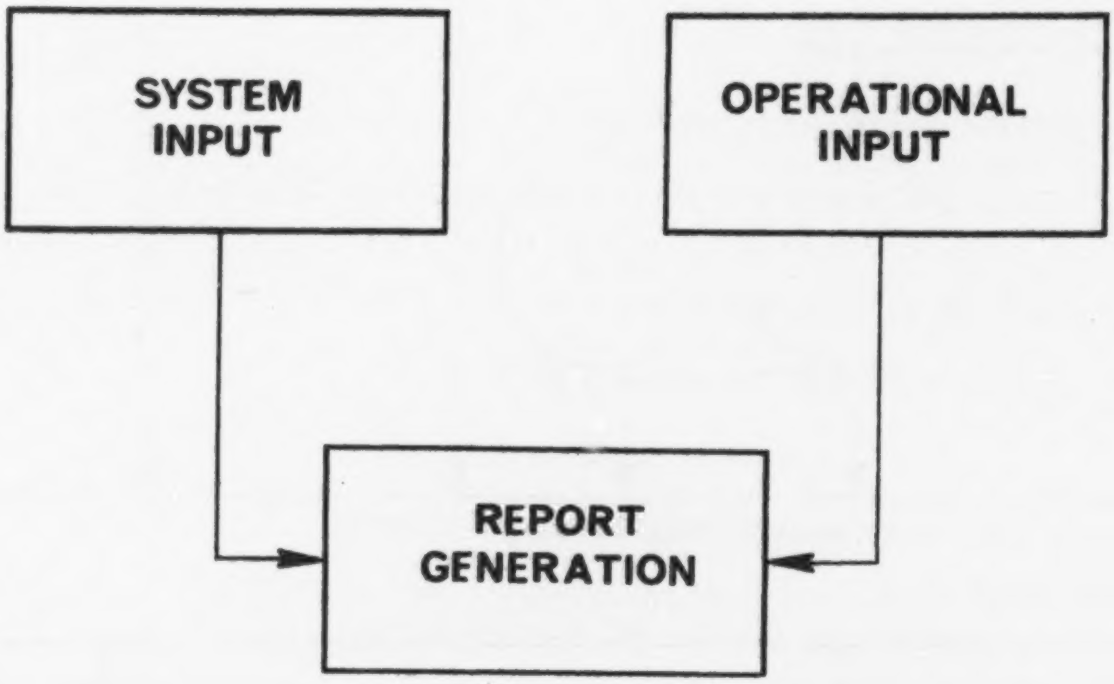

SYSTEM INPUT
OPERATIONAL INPUT
REPORT GENERATION

Chart 2

## AIMS VERSION III

## SYSTEM STRUCTURE

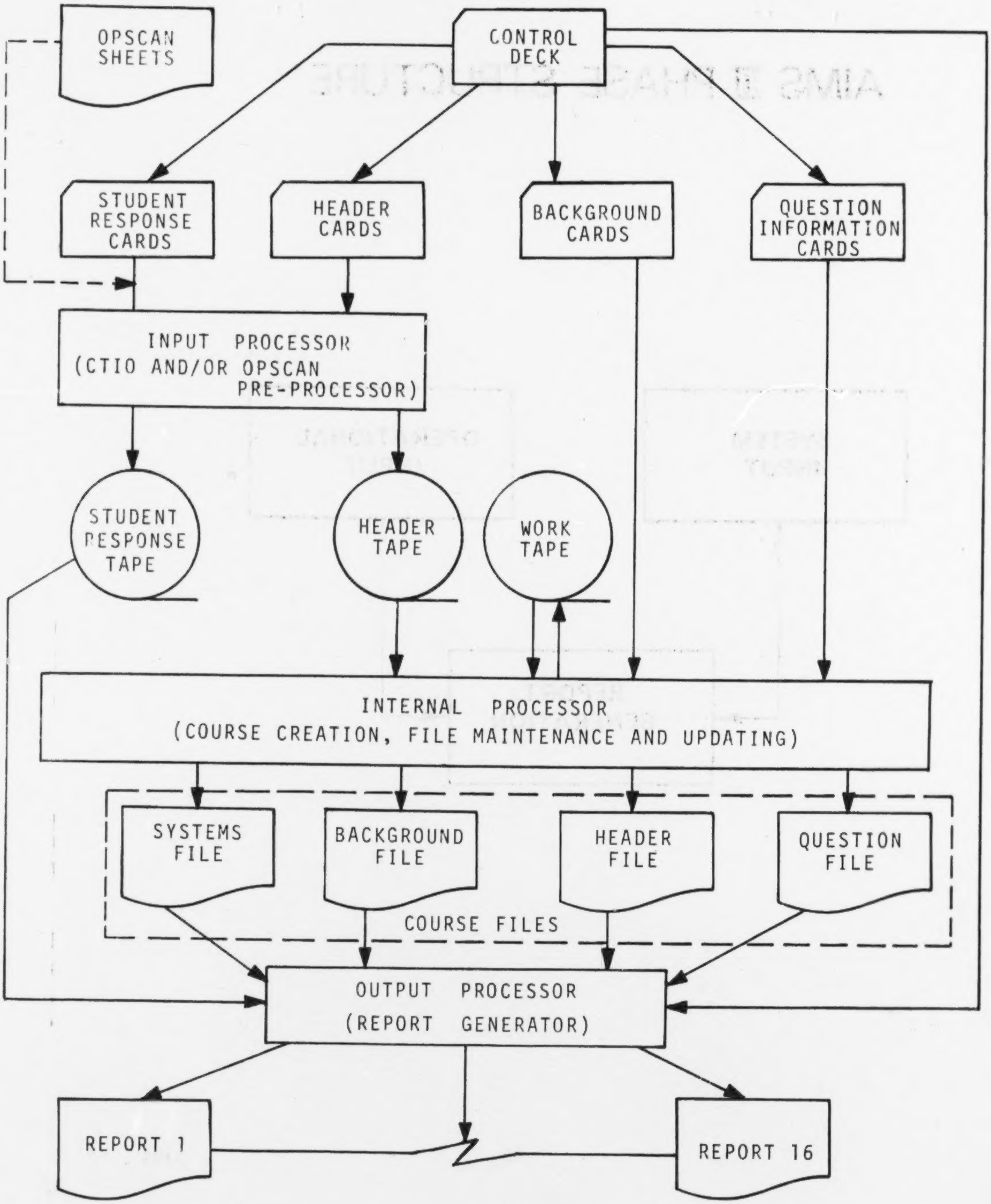

OPSCAN SHEETS
CONTROL DECK
STUDENT RESPONSE CARDS
HEADER CARDS
BACKGROUND CARDS
QUESTION INFORMATION CARDS
INPUT PROCESSOR (CTIO AND/OR OPSCAN PRE-PROCESSOR)
STUDENT RESPONSE TAPE
HEADER TAPE
WORK TAPE
INTERNAL PROCESSOR (COURSE CREATION, FILE MAINTENANCE AND UPDATING)
SYSTEMS FILE
BACKGROUND FILE
HEADER FILE
QUESTION FILE
COURSE FILES
OUTPUT PROCESSOR (REPORT GENERATOR)
REPORT 1
REPORT 16

Chart 3

# COURSE STRUCTURE

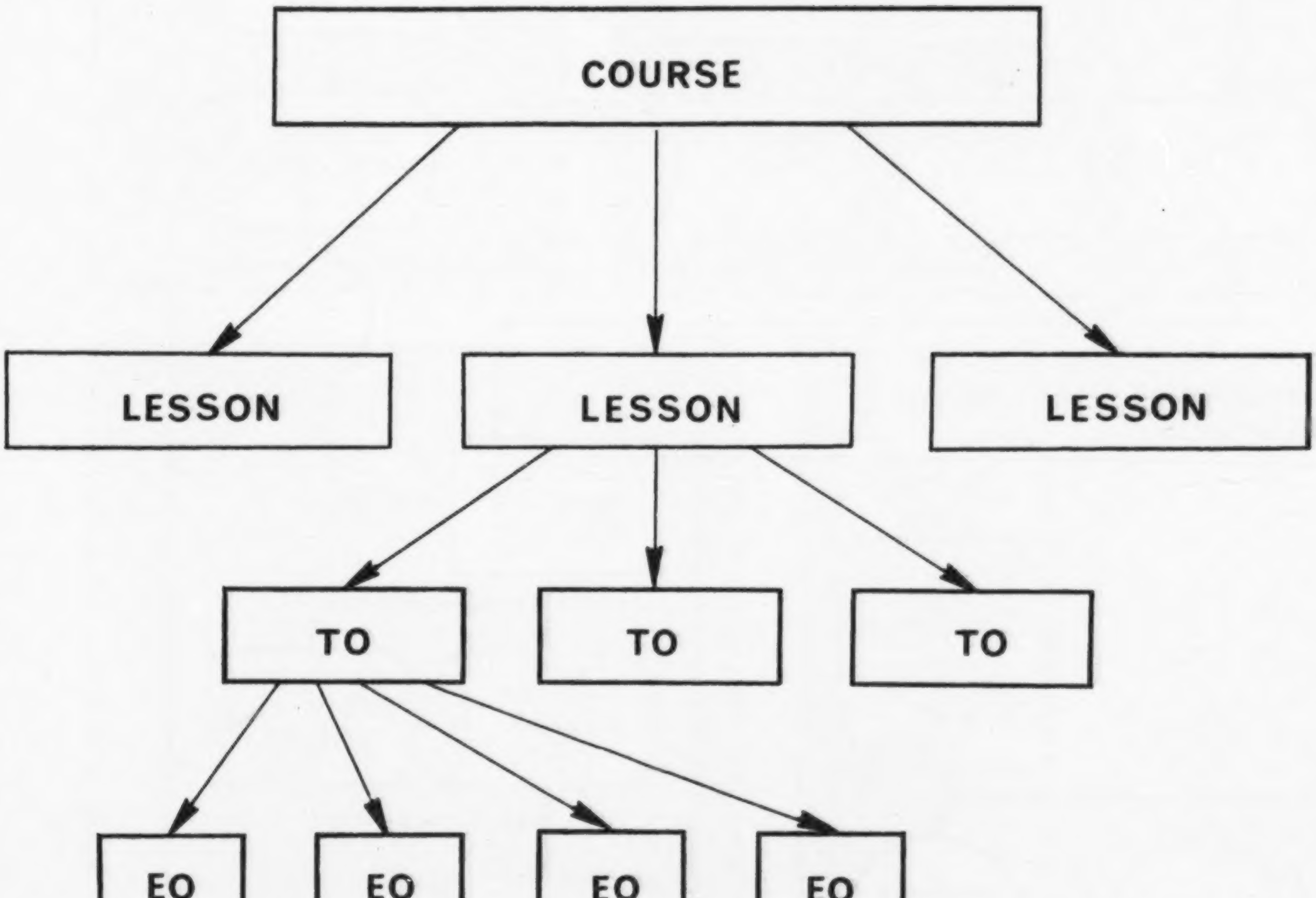

COURSE
LESSON
LESSON
LESSON
TO
TO
TO
EO
EO
EO
EO
Q
Q
Q

Chart 4

AIM III PROGRAM STRUCTURE

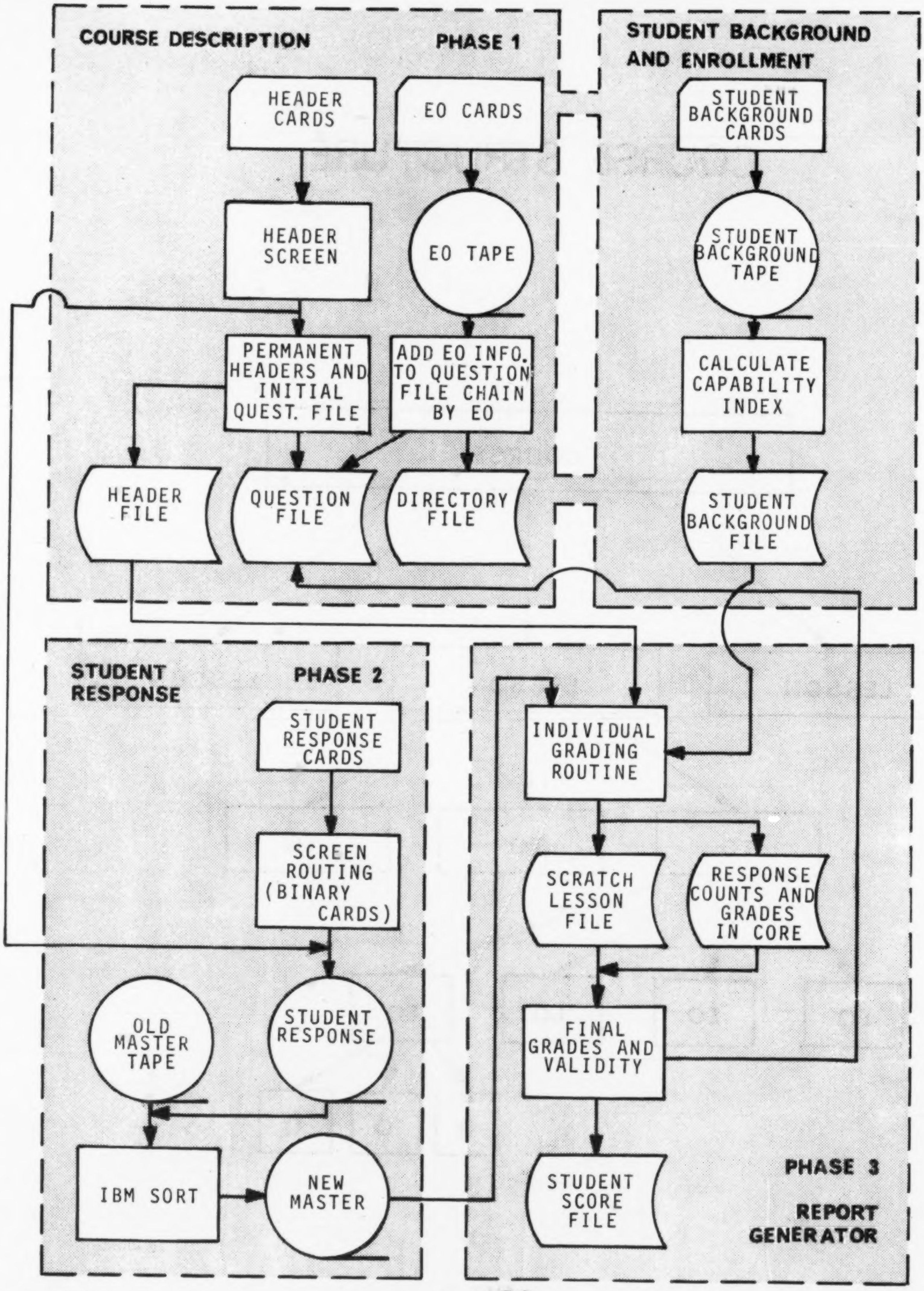

COURSE DESCRIPTION
PHASE 1
HEADER CARDS
EO CARDS
HEADER SCREEN
EO TAPE
PERMANENT HEADERS AND INITIAL QUEST. FILE
ADD EO INFO. TO QUESTION FILE CHAIN BY EO
HEADER FILE
QUESTION FILE
DIRECTORY FILE
STUDENT BACKGROUND AND ENROLLMENT
STUDENT BACKGROUND CARDS
STUDENT BACKGROUND TAPE
CALCULATE CAPABILITY INDEX
STUDENT BACKGROUND FILE
STUDENT RESPONSE
PHASE 2
STUDENT RESPONSE CARDS
SCREEN ROUTING (BINARY CARDS)
OLD MASTER TAPE
STUDENT RESPONSE
IBM SORT
NEW MASTER
INDIVIDUAL GRADING ROUTINE
SCRATCH LESSON FILE
RESPONSE COUNTS AND GRADES IN CORE
FINAL GRADES AND VALIDITY
STUDENT SCORE FILE
PHASE 3
REPORT GENERATOR

Chart 5

## AIMS VERSION III

## CREATING A STUDENT BACKGROUND FILE

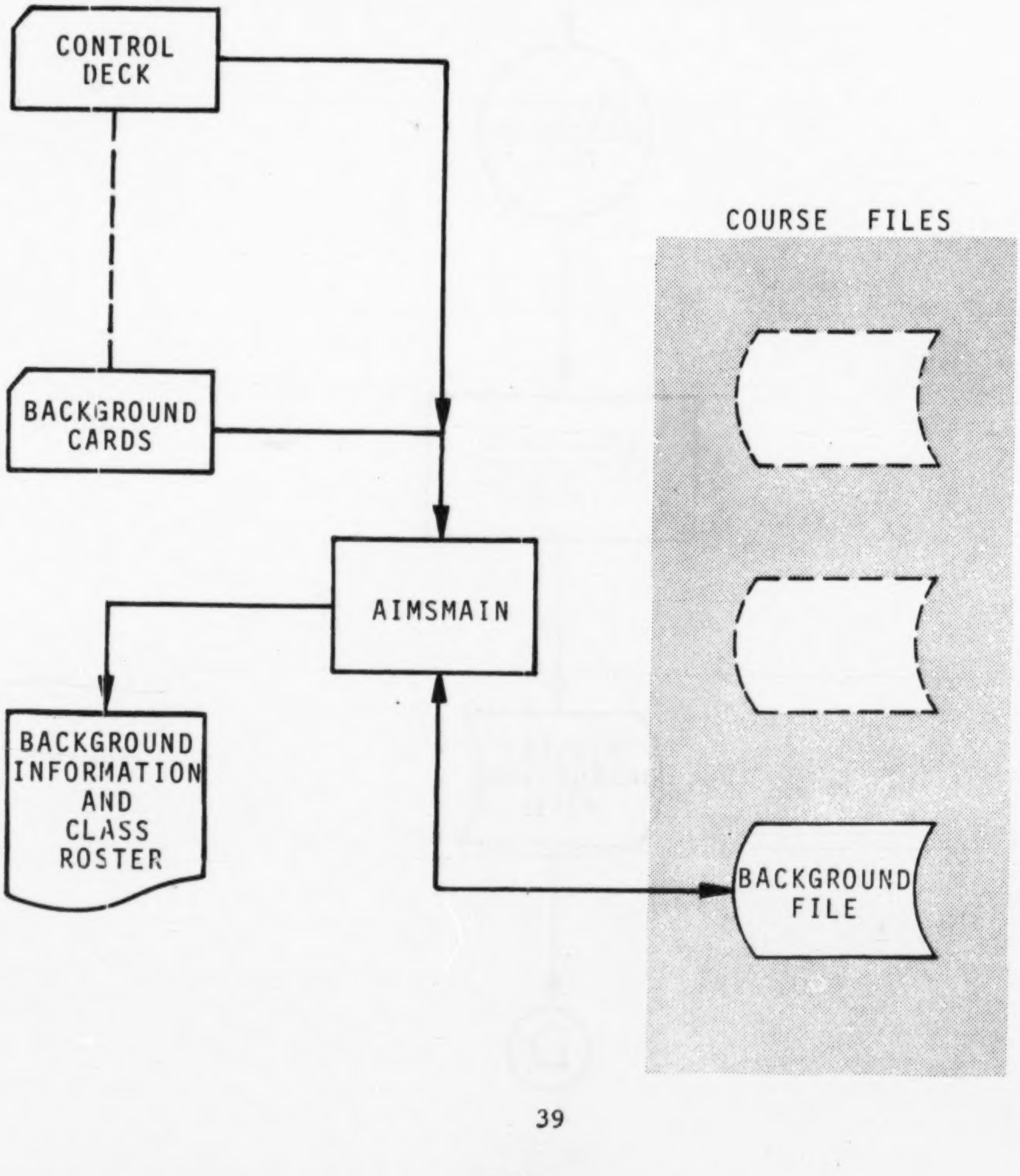
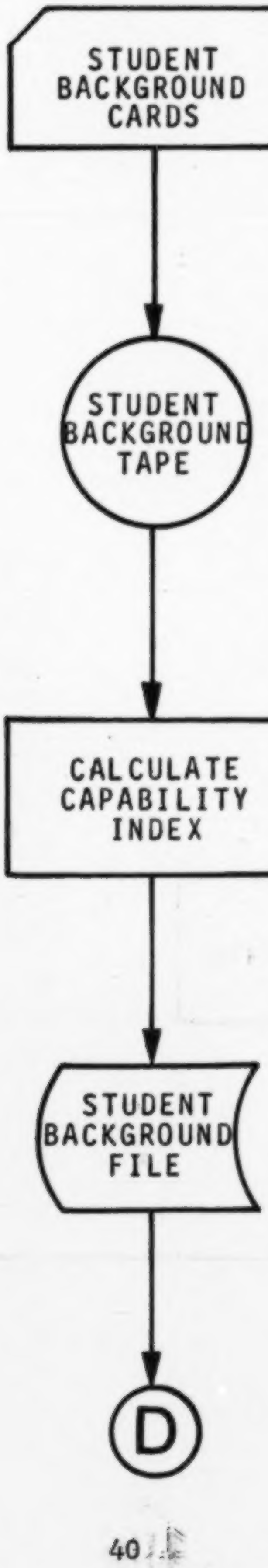

CONTROL DECK
BACKGROUND CARDS
AIMSMAIN
BACKGROUND INFORMATION AND CLASS ROSTER
COURSE FILES
BACKGROUND FILE

Chart 6

## STUDENT BACKGROUND AND ENROLLMENT


STUDENT BACKGROUND CARDS
STUDENT BACKGROUND TAPE
CALCULATE CAPABILITY INDEX
STUDENT BACKGROUND FILE
D

## COURSE DESCRIPTION

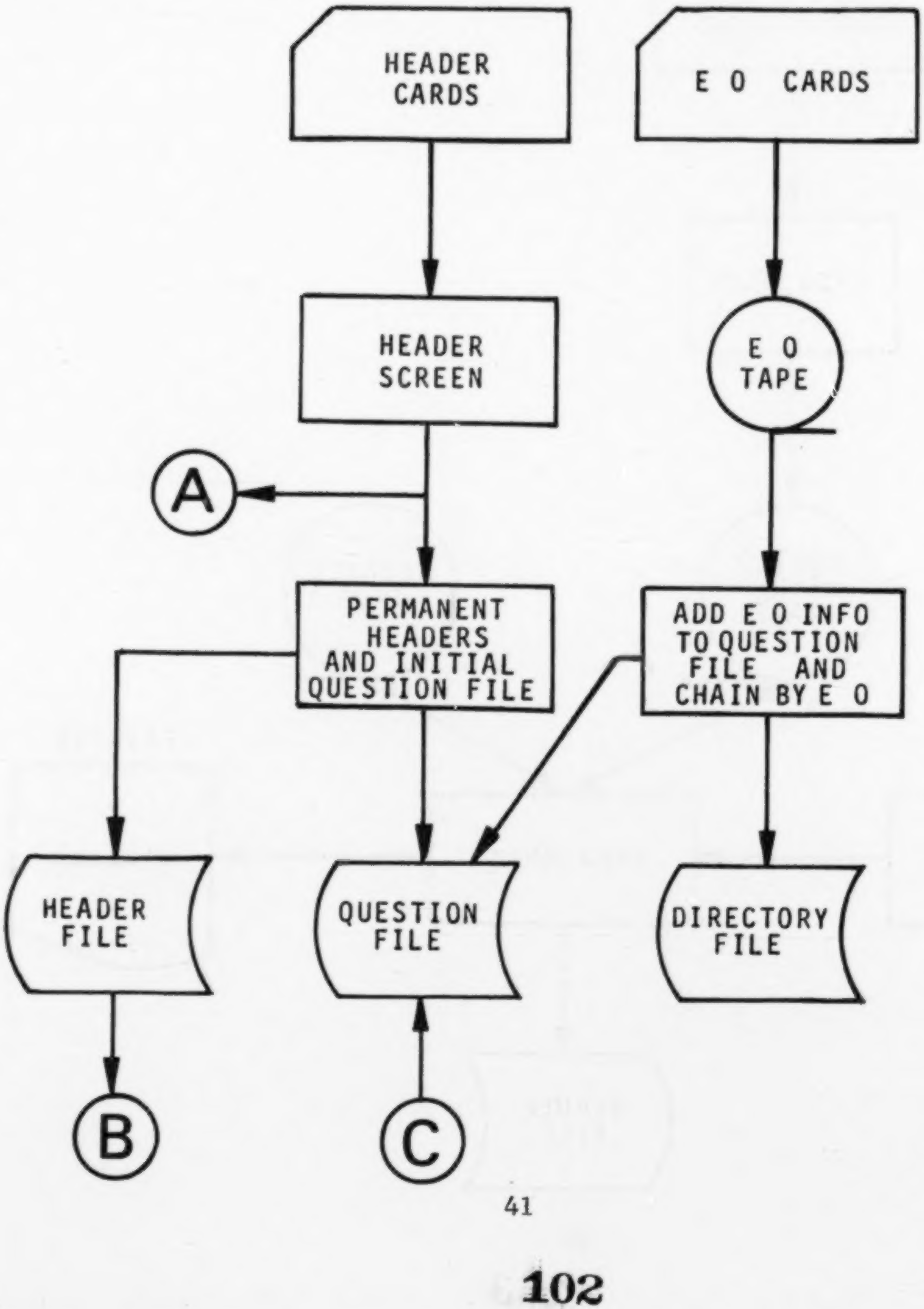

HEADER CARDS
E O CARDS
HEADER SCREEN
E O TAPE
A
PERMANENT HEADERS AND INITIAL QUESTION FILE
ADD E O INFO TO QUESTION FILE AND CHAIN BY E O
HEADER FILE
QUESTION FILE
DIRECTORY FILE
B
C

Chart 8

## HEADER FILE

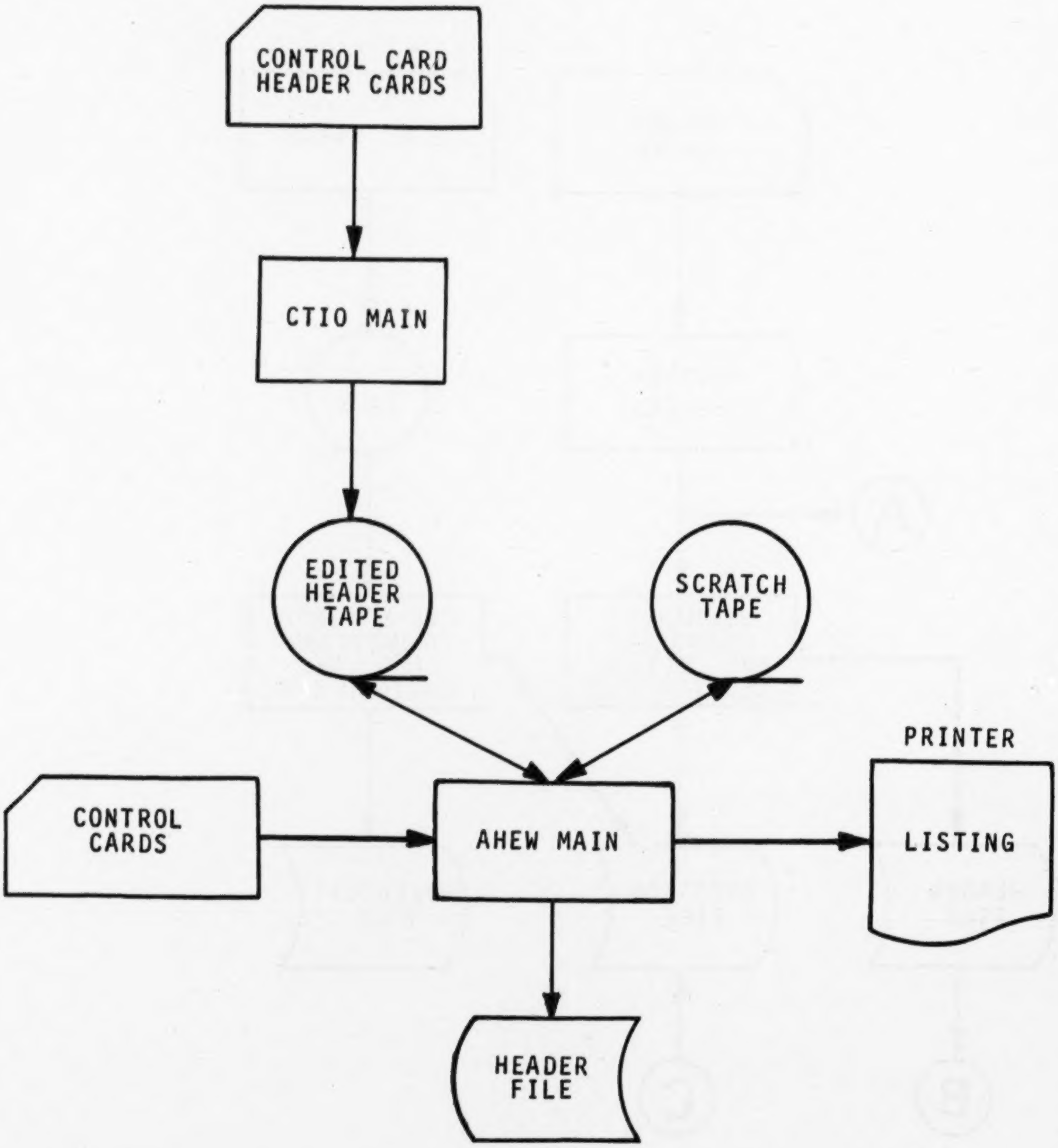

CONTROL CARD
HEADER CARDS
CTIO MAIN
EDITED HEADER TAPE
SCRATCH TAPE
PRINTER
CONTROL CARDS
AHEW MAIN
LISTING
HEADER FILE

Chart 9

## AIMS VERSION III

## FILE MAINTENANCE AND UPDATING

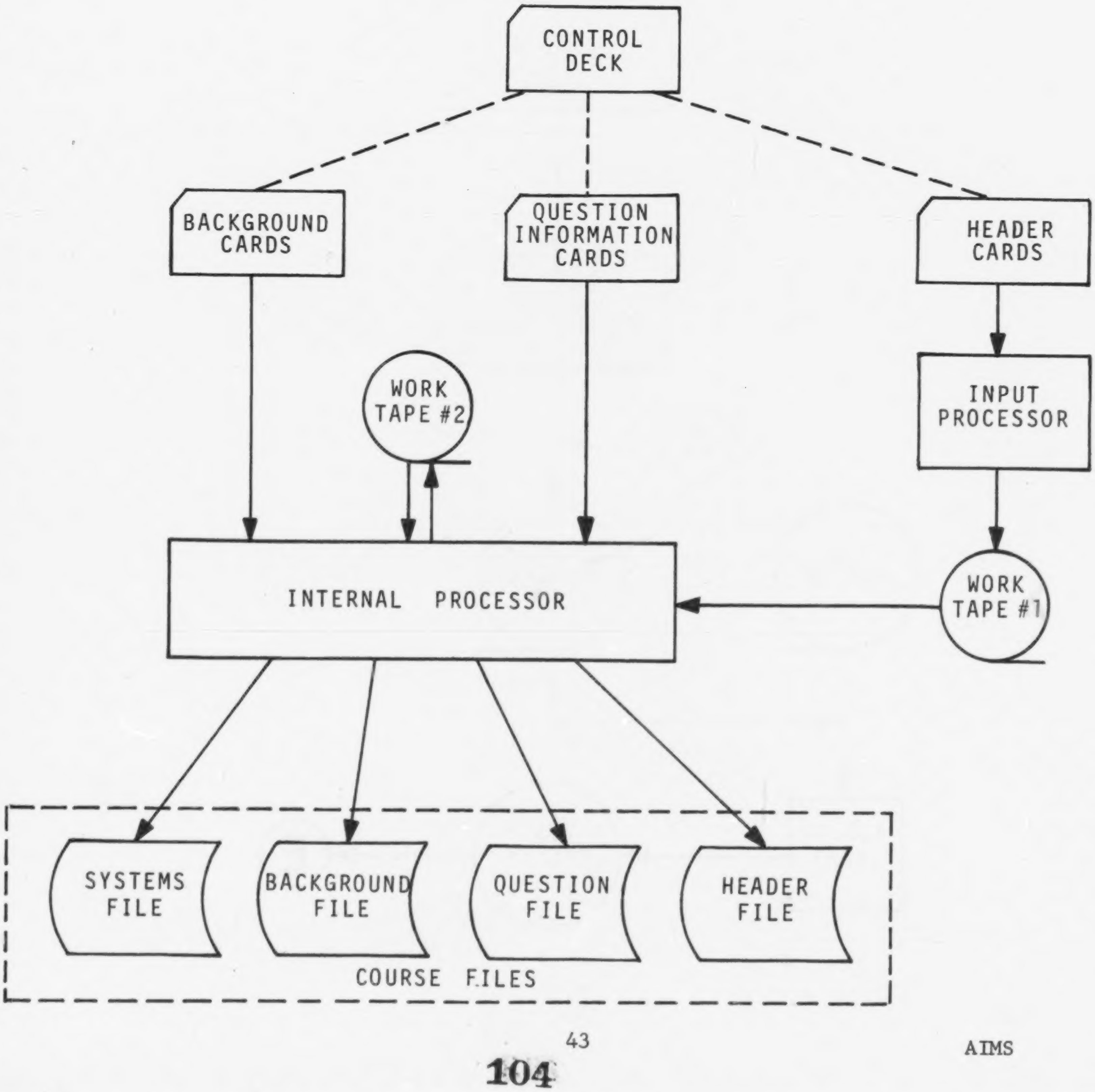

CONTROL DECK
BACKGROUND CARDS
QUESTION INFORMATION CARDS
HEADER CARDS
WORK TAPE #2
INPUT PROCESSOR
INTERNAL PROCESSOR
WORK TAPE #1
SYSTEMS FILE
BACKGROUND FILE
QUESTION FILE
HEADER FILE
COURSE FILES

Chart 10

## STUDENT RESPONSE

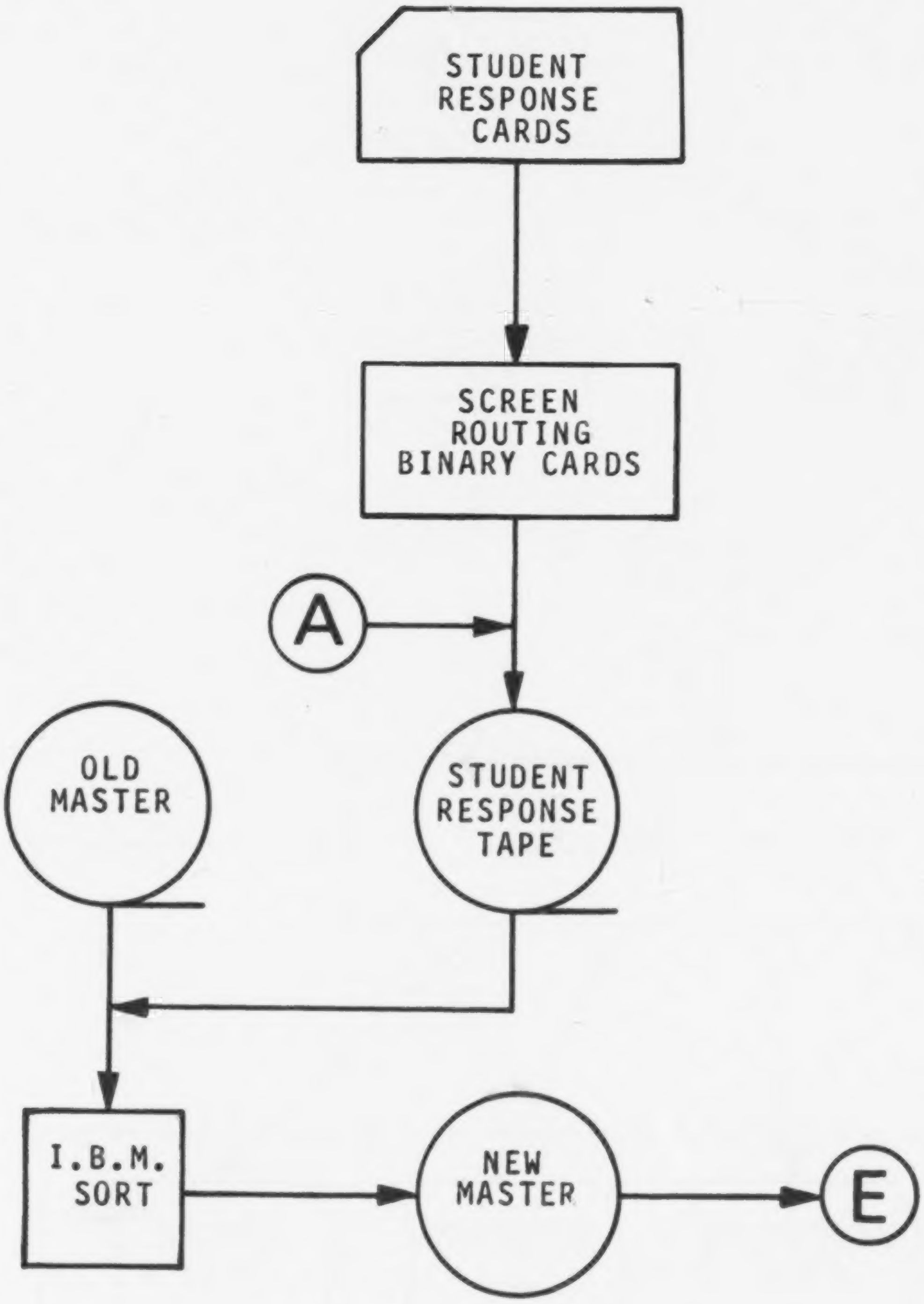

STUDENT RESPONSE CARDS
SCREEN ROUTING BINARY CARDS
A
OLD MASTER
STUDENT RESPONSE TAPE
I.B.M. SORT
NEW MASTER
E

Chart 11

## AIMS VERSION III

## RESPONSE TAPE PRODUCTION

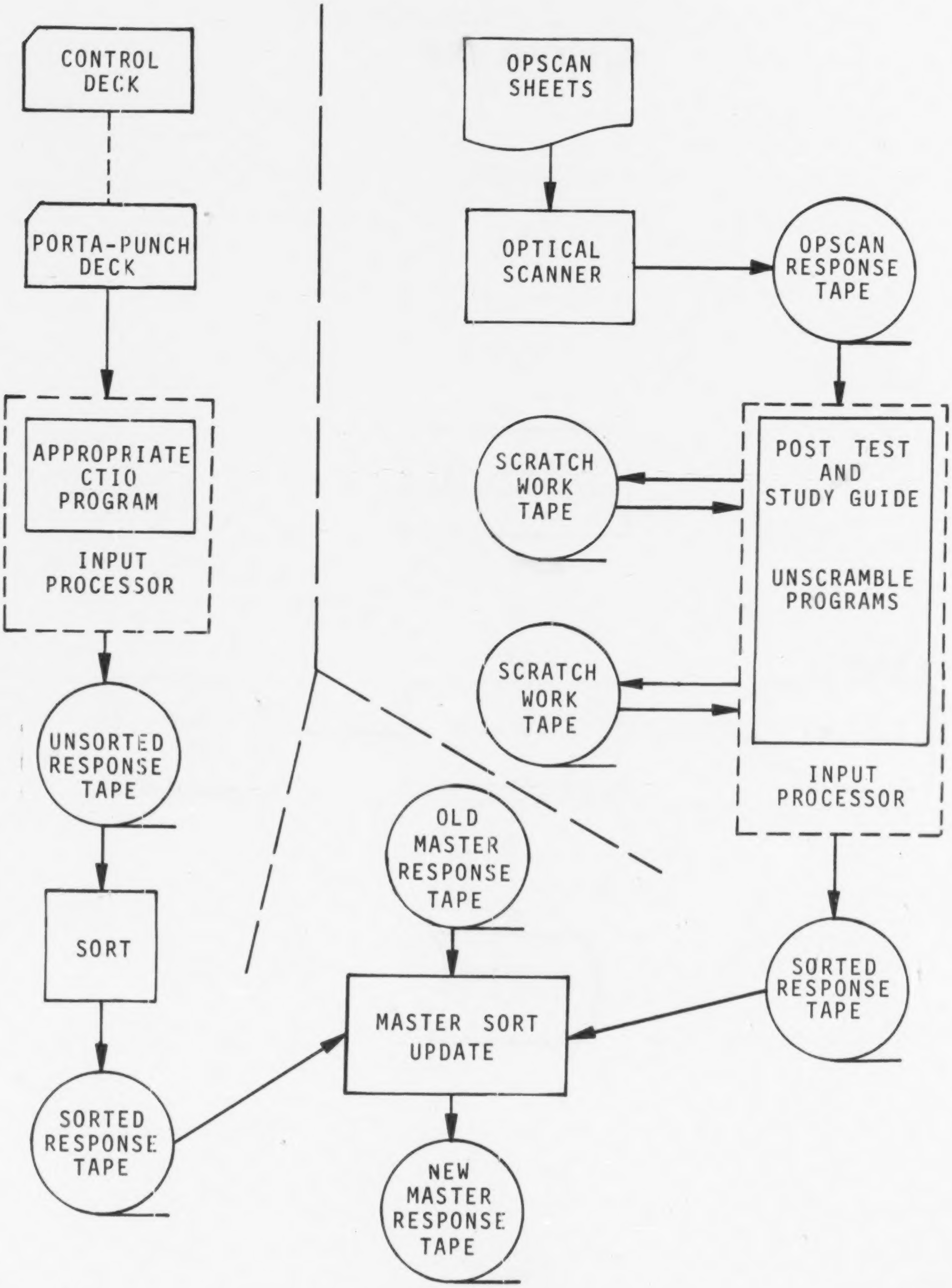
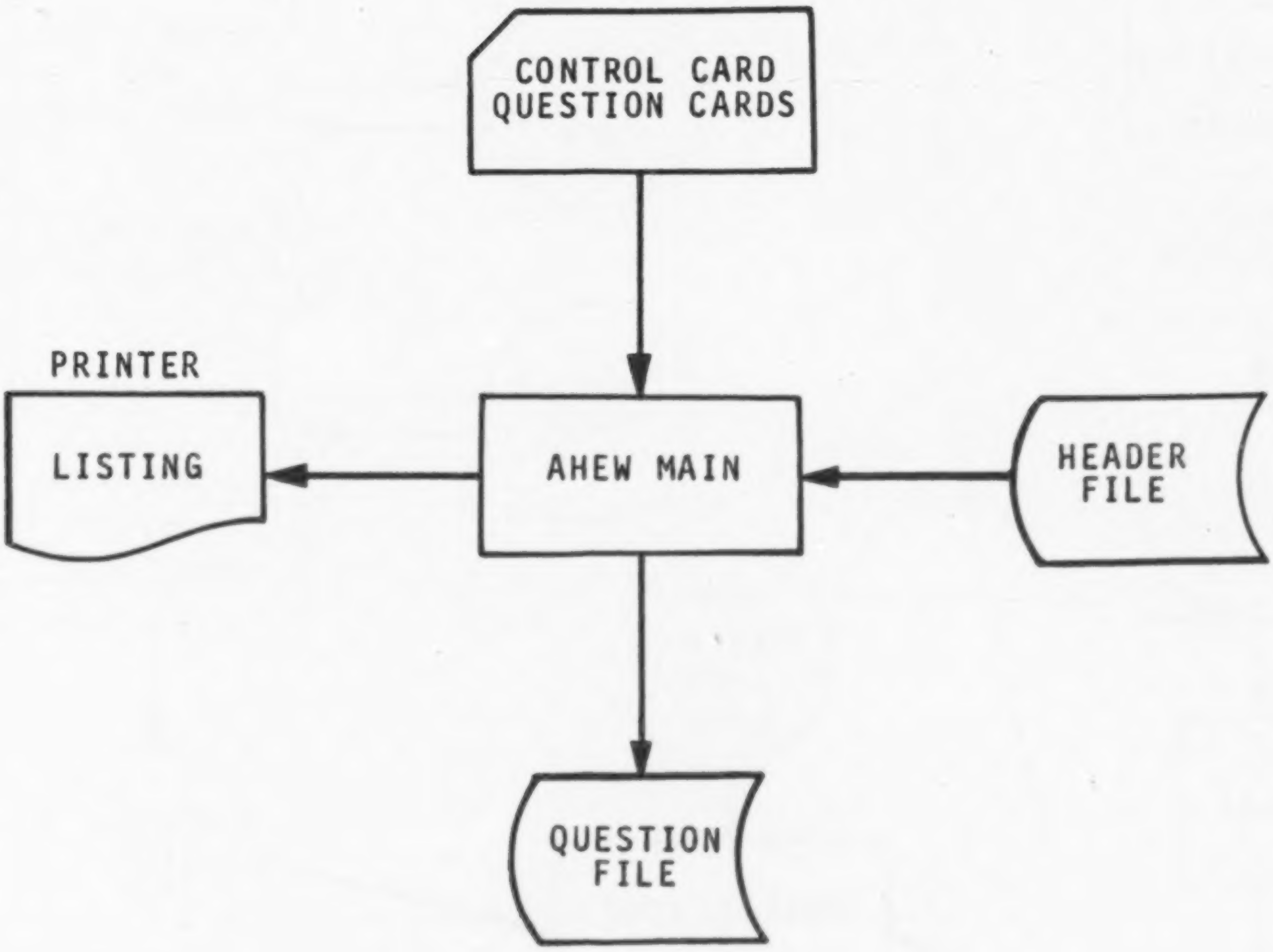

CONTROL DECK
PORTA-PUNCH DECK
APPROPRIATE CTIO PROGRAM
INPUT PROCESSOR
UNSORTED RESPONSE TAPE
SORT
SORTED RESPONSE TAPE
OPSCAN SHEETS
OPTICAL SCANNER
OPSCAN RESPONSE TAPE
SCRATCH WORK TAPE
POST TEST AND STUDY GUIDE
UNSCRAMBLE PROGRAMS
SCRATCH WORK TAPE
INPUT PROCESSOR
OLD MASTER RESPONSE TAPE
SORTED RESPONSE TAPE
MASTER SORT UPDATE
NEW MASTER RESPONSE TAPE

**Chart 12**

# QUESTION FILE


CONTROL CARD
QUESTION CARDS
PRINTER
LISTING
AHEW MAIN
HEADER FILE
QUESTION FILE

## AIMS VERSION III

## REPORT GENERATION

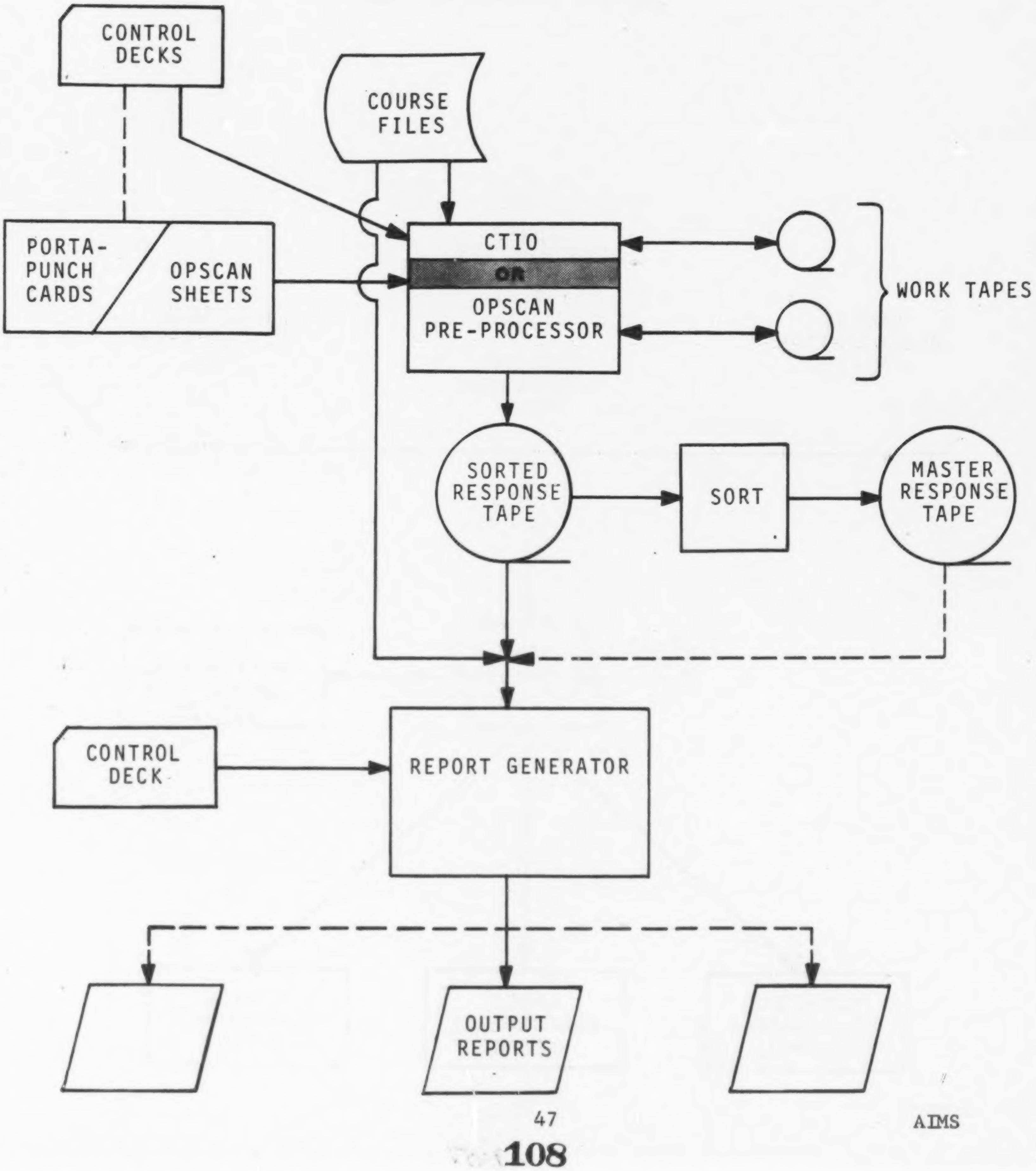
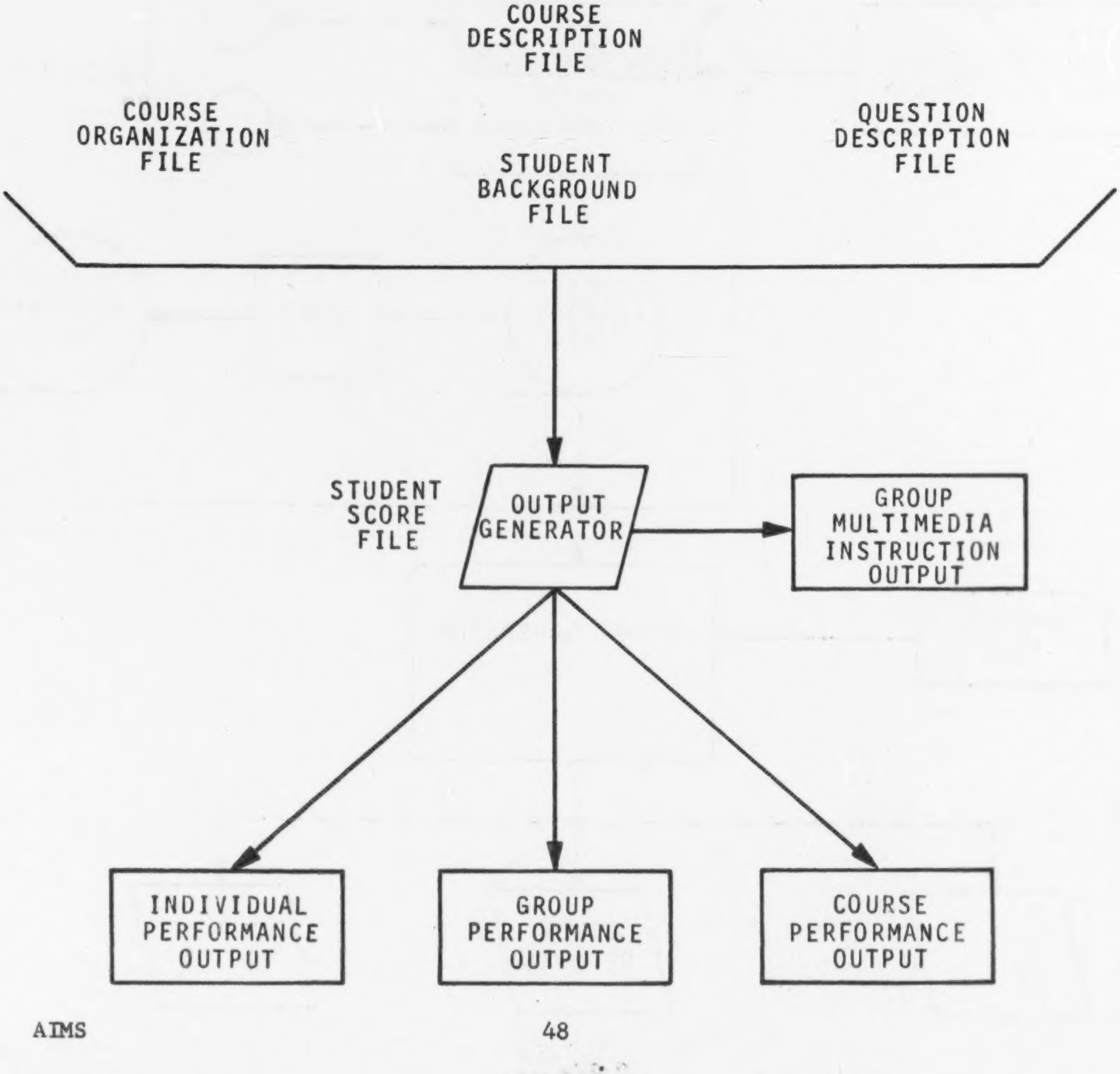
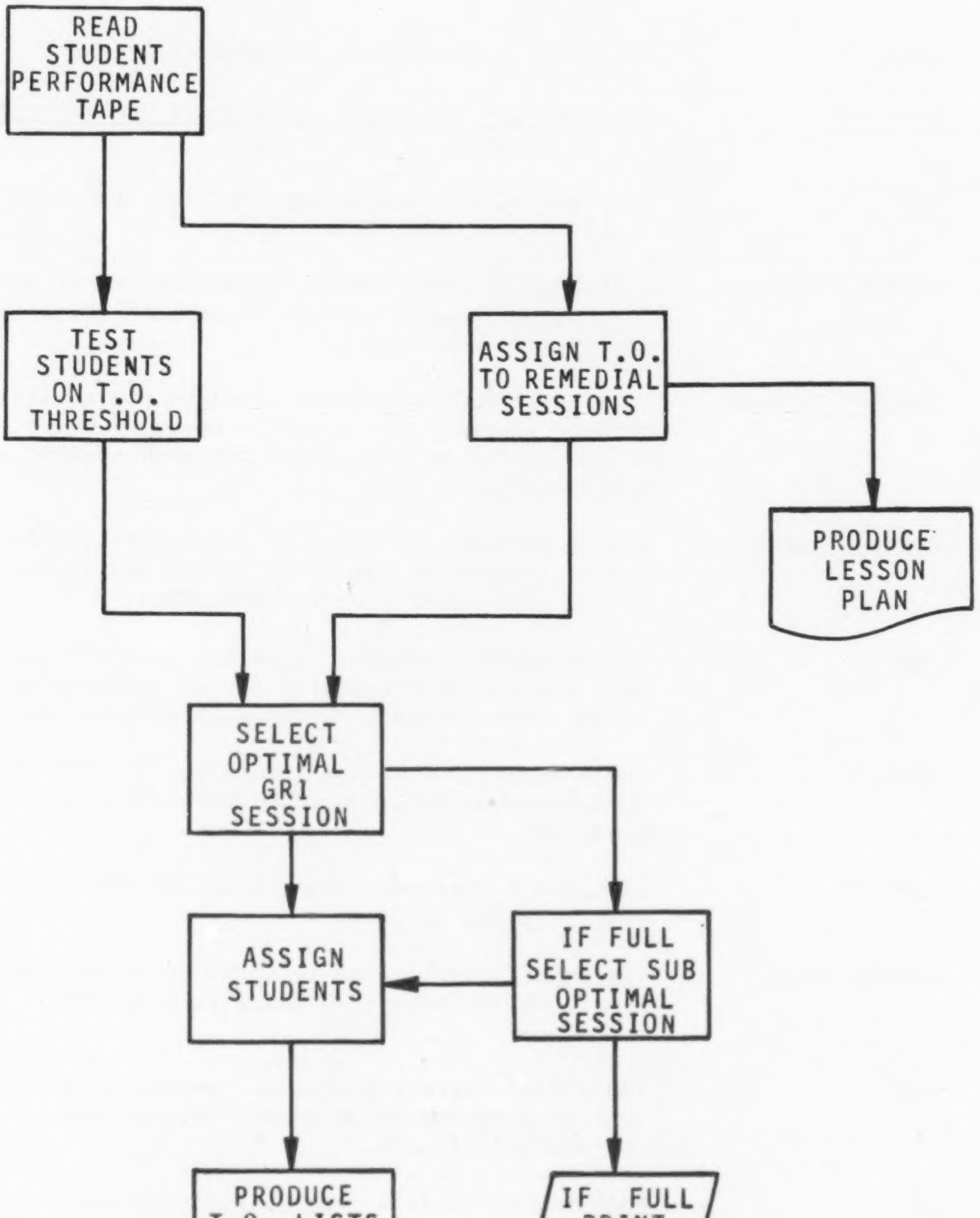

CONTROL DECKS
COURSE FILES
PORTA-PUNCH CARDS
OPSCAN SHEETS
CTIO
OR
OPSCAN PRE-PROCESSOR
WORK TAPES
SORTED RESPONSE TAPE
SORT
MASTER RESPONSE TAPE
CONTROL DECK
REPORT GENERATOR
OUTPUT REPORTS

**Chart 14**

## MONITORING OF INDIVIDUAL
## AND
## GROUP PERFORMANCE


COURSE DESCRIPTION FILE
COURSE ORGANIZATION FILE
QUESTION DESCRIPTION FILE
STUDENT BACKGROUND FILE
STUDENT SCORE FILE
OUTPUT GENERATOR
GROUP MULTIMEDIA INSTRUCTION OUTPUT
INDIVIDUAL PERFORMANCE OUTPUT
GROUP PERFORMANCE OUTPUT
COURSE PERFORMANCE OUTPUT

# SYSTEM LOGIC-GRI MODULE


READ STUDENT PERFORMANCE TAPE
TEST STUDENTS ON T.O. THRESHOLD
ASSIGN T.O. TO REMEDIAL SESSIONS
PRODUCE LESSON PLAN
SELECT OPTIMAL GRI SESSION
ASSIGN STUDENTS
IF FULL SELECT SUB OPTIMAL SESSION
PRODUCE T.O. LISTS AND ROSTERS
IF FULL PRINT MESSAGE

# GLOSSARY

NOTE: Special terminology contained in AIMS Reports 13 and 14 is listed in one section at the end of this glossary.

| | |
|---|---|
| AIMS | Automated Instructional Management System |
| AIMS III | The revised form of the management system used during Phase II of the project. |
| AMP | Articulated Multimedia Physics; also referred to as Physics 4001 (N.Y.I.T.). |
| ANSWER MATRIX | A listing in chart form of question number and an array of answer choices as applied to multiple choice question format. |
| CONCEPT CATALOG | A coded list of algebraic concepts and skills, used to identify the probable cause of error in responding to a question designed to test a specific MBO. |
| CONTROL SHEET | A form on which is recorded all distribution and collection of materials in the operation of a course under the SIM/AIMS MODE. |
| CSN | Course student number. A number assigned to each student on the course roster. Generally in the same sequence as the alphabetical order. |
| C/W | The heading of a column indicating whether the answer choice to a question was correct (C) or wrong (W). |
| CUM/AVE | Cumulative average. The average of the previous weekly scores to date. |
| CUTOFF LEVEL | The cutoff level, also referred to as threshold level, is the tolerated percentage of error incedence. |
| DOS | IBM's disc operating system. Series of computer control programs which permit the machine to operate effectively. |
| EO | Enabling objective. An MBO prerequisite to achieving a TO or a sub-set belonging to a TO. |

| | |
|---|---|
| GCHS | Glen Cove High School |
| LATENT IMAGE RESPONSE SHEET | A response form that records the student's answer choice at the same time that it reveals a page number printed in invisible ink. |
| LESSON | In the physics program (AMP) a lesson is equivalent to a volume. The computer printouts use lesson and volume interchangeably. |
| MATH 3012<br>M 3012<br>COURSE 30 | Course in elementary algebra using the PMC I at N.Y.I.T., Special Education Department. |
| MBO | Measurable behavioral objective. A statement of a specific concept or skill that is to be learned by a student and the conditions under which his ability to demonstrate his knowledge is to be tested. |
| MBO CROSS REFERENCE | A listing of all MBO numbers and the questions that relate to them. |
| MESSAGE | A statement in the computer printout either describing the nature of the objective or listing a remedial assignment (prescription). E.g., 597/27.1-5 means in book 597, the student is assigned problems 1-5 on page 27. |
| N.Y.I.T. | New York Institute of Technology, Old Westbury, New York 11568. |
| OS | IBM's operating system. Series of computer control programs which permit the machine to operate effectively. |
| PHYSICS 4001<br>P 4001<br>COURSE 40 | Course in Physics at N.Y.I.T., Special Education Department using the AMP Program. |
| PMC | Programmed Mathematics Continuum Level I - Elementary Algebra. |
| PRESCRIPTION | A remedial assignment appearing on a test printout when a student has failed a particular question (see MESSAGE). |
| PSSC | Physical Science Study Committee. |
| REPORT | "Report" and "printout" are used interchangeably. |

| | |
|---|---|
| SEGMENT<br>SEG. | A part of a volume. In the Math Program (PMC) a volume is divided into five segments. In the Physics Program each lesson has only one segment. |
| SIM/AIMS MODE | A Student-Instructor managed routine controlling the distribution and collection of materials. It contains the option of sending the response form to the computer for processing or of having them hand graded as a back-up, fail-safe feature. |
| STUD. GDE.<br>S.G. | Study Guide volume, one of a set of instructional materials using a branching program with multiple-choice questions and presented in scrambled pagination form. The latent image response sheet is employed in working through the S.G. |
| STUD. GDE. 1 | An abbreviation in printouts employing Segment 1 of the Study Guide, Segment 2 of the Study Guide, etc. |
| STUD. | A short form for student. |
| THRESHOLD LEVEL | See cutoff level. |
| TO | Terminal objective. A major MBO. |
| TYPE<br>TYP. | Type of input arising from student response to different parts of a lesson or volume. Type 1, Pretest; Type 2, Posttest; Type 3, Homework; Type 4, Study Guide Segment; Type 5, Worksheet Assignment. |
| VICAR | Varied Input Computer Assembled Records. The original computer program comprising 13 printouts later assimilated into AIMS III. |
| VISIBLE PAGINATION | A key for the use of the instructor of the information that appears in the latent image response sheet. |
| VOLUME<br>VOL. | An individually bound basic unit in the PMC course equivalent to a lesson in the AMP Course. |

# 4

# EMPIRICAL COURSE DEVELOPMENT MODEL

*An instruction manual for the construction of individualized, self-paced, self-healing, multi-media instructional systems; distillation of the experience gained in applying the systems approach to develop the model programs.*

# ACKNOWLEDGMENT

The principal investigator extends his thanks to Dr. William Deterline, Dr. Robert Branson, and Mr. Stanley Schwartz for their preparation of the manuscript; and to Prof. Harvey Pollack and Dr. Robert Finkel for editing the manuscript into the present form.

# THE EMPIRICAL COURSE DEVELOPMENT MODEL

## Table of Contents

EXPLANATION OF THIS REPORT, PURPOSE, FORMAT, AND USE .............. 3

GENERAL DESCRIPTION OF THE MODEL .................................. 7

PHASE I: IDENTIFICATION AND STRUCTURING OF COURSE OBJECTIVES

- A: Overview of Phase I .................................... 12
- B: Abbreviated Descriptions of Procedures .................. 15
- C: Detailed Procedural Steps ................................ 16
- D: Procedural Flowchart ..................................... 22

PHASE II: COURSE DESIGN

- A: Overview of Phase II .................................... 23
- B: Abbreviated Descriptions of Procedures .................. 26
- C: Detailed Procedural Steps ................................ 27
- D: Procedural Flowchart ..................................... 36

PHASE III: COURSE MANAGEMENT AND MAINTENANCE

- A: Overview of Phase III ................................... 37
- B: Abbreviated Descriptions of Procedures
  - Section One: Management of Course Implementation ........ 40
  - Section Two: Analysis of Results and Revision Decisions . 42
- C: Detailed Procedural Steps
  - Section One: Management of Course Implementation ........ 44
  - Section Two: Analysis of Results and Revision Decisions . 61
- D: Procedural Flowcharts .................................... 73

SUPPLEMENT: Special reference articles, additional miscellaneous procedural guides, etc. .............................. 75

REFERENCES: ................................................ 97

EMPIRICAL COURSE DEVELOPMENT MODEL

Table of Figures

FLOW CHART 1 ................................22
TABLE 1 ....................................29
FLOW CHART 2 ................................36
TABLE 2 ....................................62
FLOW CHART 3 ................................73
FLOW CHART 4 ................................74

# THE PURPOSE, FORMAT, AND APPLICATION OF THIS REPORT

## PURPOSE

To avoid a product of limited application, the instructional and management materials described in this report have been completely generalized to make them suitable for any discipline. Testing and validation activities were necessarily conducted in connection with specific courses but emphasis was continuously laid on broadening these assessments to include all other fields of study. The courses involved in this study were the United States Naval Academy physics course, the Articulated Multimedia Physics course (NYIT), the Data Processing course (NYIT), and the Programmed Mathematics Continuum (NYIT).

The methodology of instructional design--a combination of art and technology--was the real target of the investigation. Since the requirements of the Naval Academy project included the development of a self-paced multimedia course in physics as well as an interdisciplinary model, a substantial part of the research took place in this field. All three of the courses, however, were developed through the use of a set of procedures and techniques identified and described in the original proposals and the subsequent Project Reports.

The complete set of techniques and their systematic application as described in this document constitutes the course-development model. It presents a system for maintenance, continuous upgrading, improving individualization, and iterative optimization for any course in the educational spectrum. The approach to the development of instructional and management strategies is completely empirical.

The presentation of the model in this document is structured as a set of *procedural descriptions* addressed specifically to the individuals who are to carry out the tasks. It is felt that this format is easier to use by the people directly concerned with course development and lends itself to ready examination, review, and evaluation.

## FORMAT

The material that follows the introductory information presents the model in three phases:

I. Course Objectives
II. Course Design
III. Course Management and Maintenance

The material related to each phase consists of four components:

Part A. General overview, rationales, and description of purpose and approach;

Part B. Abbreviated descriptions of the procedural steps;

Part C. Expanded and detailed descriptions of the procedures in step-by-step form;

Part D. Flow chart representation of the steps, including all feedback relationships.

Reference materials, additional procedural guides, and sources for additional background information for course developers are identified in the Exhibits.

## USE

This report can be used in a number of ways and for a variety of purposes. The basic philosophy underlying the model is contained in Part A of each phase. A sophisticated reviewer interested in gaining an overview might scan only Parts A and B of each phase. The more knowledgeable course developer, experienced with empirical, iterative course development models, might scan only Part D of each of the phases. An individual considering the model for possible application or evaluation purposes at a broad overview level might refer to Parts A and D. The potential course developer planning to utilize the model will, of course, study the complete model and will follow the detailed procedural guides that make up Part C of each phase.

Although the model is presented in the form of directions for carrying out certain procedures, a relatively high level of sophistication, training, and experience is assumed on the part of individuals who are to utilize and implement the model. Empirical course development requires considerable expertise in empiricism and data analysis, instructional decision-making, subject-matter, aid in test item development and analysis. Those competencies have been available for decades, but the concept of empirical course development, validation procedures, and accountable course management are comparatively new in education. This empirical course development model is one systematic way to make use of those old and new approaches for the improvement of instruction.

The model itself requires a relatively high level of expertise for effective implementation. Because this is not always easy to find in settings where the model would be most helpful, New York Institute of Technology is presently involved in the development of instructional procedures and materials, and in a dissemination project that will result in the development of the necessary competencies, knowledge, skills, and attitudes required for maximum effective utilization of the model.

The model as described here might be referred to as a "mini-model." It has been simplified to a level appropriate to the two main purposes stated earlier; that is, for further optimization of the physics, mathematics, and data processing courses, and dissemination in a practical and usable form. While all of the essential steps are included, this presentation will deal only with the primary functions of the model--course development relying on empiricism to produce and maintain a system that effectively achieves its objectives. Much of the potential for basic instructional research is bypassed in the model, not because that potential is considered to be unimportant, but because that is not the purpose for which the model was developed. Although a variety of experimental manipulations, treatments, and analyses were a part of the project in which the model was refined, the hypotheses upon which the experimentation was based are discussed in other portions of the Final Project Report. These have no direct bearing on the utilization of this version of the model.

It should be stressed that any *empirical* model contains, by definition, an experimental methodology. The model provides a systematic set of procedures for developing a "first-cut" version of a course, and through the collection, analysis, and interpretation of data, for making revisions on the basis of those interpretations. Provision is also made for continuing the test and revision cycle until the course has been optimized. Each use of the developing course is itself an experiment, a search for deficiencies that must be removed. Additional experimentation can be conducted within the course development series, exploring such factors as individual student characteristics, media, and prescribed options. Research specialists can utilize the basic model as a vehicle for conducting additional research, but it should be remembered that the model itself is primarily concerned with fundamental course development nature. For that reason, additional research is not discussed as a part of the basic model presented here.

One of the dubious assumptions that accompanies many approaches to course development is the view that a competent group of subject matter experts and experienced teachers can develop an adequate finished product without subjecting their course to an experimental series of tests and revisions using students to test the structure. The philosophy that a course should effectively teach every student is only partly accepted in nonempirical approaches of that sort; it is expected that a student will not learn everything included in the course, and that failures are indicated by low grades. Norm-referenced tests with their emphasis on discriminating among students further confound the problem. Item design and analysis is more concerned with arriving at items that discriminate at approximately the 50% level than with concern for identifying competence on each of the course objectives. Further, courses are generally designed as clusters of *content* to be presented, with relatively little attention given to the *outcomes* for which that content is presented.

A major step forward is provided by the use of behaviorally defined objectives. These objectives specify the desired learning outcomes in terms of competence as it is to be demonstrated by the student upon completion of the instruction. An additional step forward is taken when criterion-referenced tests are employed to measure directly the specified student performance capabilities. The objectives are the link which ties student performance on criterion check items to the learning experience. But this is not enough; what is needed is a philosophy that says that *instruction must be designed to meet certain specifications in terms of student performance capabilities, and everything necessary must then be done to meet those specifications.* The philosophy is available in the "accountability principle." The methodology required to implement that philosophy is available in the empirical course development approach exemplified by this model. And, of course, use of the computer as a tool makes possible more precise and immediate analysis of the effectiveness of the course components.

# THE EMPIRICAL COURSE DEVELOPMENT MODEL

## GENERAL DESCRIPTION OF THE MODEL

The word "model" can refer to a variety of conceptual structures; a form of theory, a representation of data or method of representing data, an "ideal" operation of some sort, or a structure to be emulated. In the present context the model is a system--a set of interrelated functions, procedures, steps, and activities, each with its own specifications of output or product and its own precise methodology. The model consists of a series of processes, each designed to accomplish a specified task. All outputs are either products or techniques related to these processes. The model's overall purpose is to produce effective and efficient courses of instruction, including all materials (or their selection), and all management or implementation and utilization procedures. The model must also provide a means for developing accountability within the structure of each course and an empirical methodology for developing and managing accountable courses. The empirical methodology uses an iterative process of approaching a final course structure through a series of successive approximations, utilizing data to improve the course until a satisfactory level of effectiveness is achieved and is maintainable.

The technology of instructional objectives is the basic tool upon which the operation of the model depends. An objective is an operationally defined desired learning outcome. A course is structured, not on the basis of the content and information to be presented, but rather in terms of its purpose, defined by the competence and capabilities that the students are to attain. Many approaches and techniques have been developed for identifying, analyzing, defining, and formulating objectives. Typically the first step in instructional design is the development of the objectives in descriptive form, stating in measurable terms what the student should be able to do. The second step is the development of the criterion test, a test that evaluates the student's ability to perform the behavior described by each objective. A criterion test does not sample, but tests every objective. It must do so in a form relevant to the objective itself; multiple-choice questions, while convenient for group testing in a norm-referenced test setting, are often unacceptable in a criterion test because they do not test performance of various kinds.

In this model the first two steps are reversed in the sequence: the criterion test is developed first, and the objectives are developed in narrative form to describe to the student what competencies he is to develop next in the course sequence. This approach is used because it is easier to learn, easier to carry out, and has a greater probability of producing design specifications that are complete, relevant, and made up of the appropriate forms of behavior. When objectives are based on descriptions of the behavior represented by criterion test questions, the developers of the test and objectives are less likely to produce trivial, low-level objectives.

The criterion test and resulting descriptive objectives represent the specifications of the terminal behavior that the course is to produce. This step produces a description of a course, not as a body of knowledge but as a set of specifications of the goal or purpose in providing the course for students. The specifications indicate exactly what *minimum* competencies and capabilities the students are to possess as a result of having taken the course. The term "minimum," as used here, should not be interpreted to be an evaluative term (with *minimum* representing poor quality, and *maximum* representing high quality). The minimum set of skills and knowledge that the students are to attain could be quite simple and low-level, or quite complex and high level. All that is intended by the use of the term "minimum" is an indication of a uniform minimum or lower level of attainment below which no student is allowed to fall. Most students will reach a level of attainment above the minimum, some far above that level. All students are to reach a level at or above the minimum.

The model is flexible enough to utilize any instructional vehicle, method, or material in various kinds of group or individualized setting. The nature of the course in terms of the instructional ingredients is almost incidental, and is not a major source of problems or difficulties. The model provides guidelines and procedures for the development of the first, untested version. But within very broad limits, any reasonably designed course regardless of its flaws can, through the series of iterative tryouts and revisions, reach the initially specified acceptable level of effectiveness as measured by student attainment of objectives.

The first version of the course, prior to student tryout and revision, can be described as an "experimental" course structure: a set of hypotheses regarding the kinds of experiences and activities required to help the students achieve the objectives. Experimental data are then collected by testing the course on students. The assumption is always made that deficiencies in terminal performance are not the fault of the student but are due to flaws in either the instructional or management components of the course. Revisions are then made to remove those flaws. The second iteration is a second experiment. The data again indicate weaknesses in the course materials or management system, and suggest suitable revisions. The iterative process is continued until the minimum level of achievement is attained by all students.

The accountability principle is embodied in the model in the requirement that a minimum attainment level must be specified. Progress evaluation and remediation techniques must then be employed in whatever form is required to assist all students in reaching that level. The sensitivity of the progress evaluation tests and other diagnostic instruments is critical, for these materials and methods are the components upon which successful development and operational management of the course depend. Much of the empirical development effort and revisions involve these components. The rigor of the system is applied primarily at the initial design phase and in the development of effective management procedures. This permits the utilization of a wide range of instructional materials and methods, specifically tied to the objectives, and "made to work" by the empirically developed management system. This approach has a number of significant advantages over models that rely on the use of programmed materials of an inflexible sort that require all students to proceed through basically the same instructional path with few by-pass options, and with comparatively few options in the selection of additional methods of materials.

In systems technology, the critical element of the empirical model is the use of "feedback" to compare the intended output of each component of the system with the actual output of that component. On an overall basis, the results on each posttest and of the final examination are expected to reach or exceed the minimum level. The actual test results are the "output" of the system--the feedback that indicates how well the system accomplished its purpose. But that form of feedback is on a broad scale, and although essential, it is only a part of the picture. The procedures in course development and management are more than a series of sequential steps; each step has its own output and its own specifications, and therefore each step can be evaluated and revised on a self-correcting basis. In an industrial design or manufacturing setting, the use of specifications and feedback provides what is called "quality control." Obviously education is not manufacturing, but the systems approach, the empirical model, the use of objective feedback, and operationally defined objectives as specifications are as relevant to the attainment of educational goals as they are to industrial success.

By definition, the empirical model must be sensitive to data. Regardless of the logic, intuition, and professional teaching experience the course developers might bring to the course, the data produced by students used as experimental subjects are critical to subsequent decisions, revisions, and course modifications.

The empirical course development model does not require that the course be individualized, or be a "packaged" course capable of functioning effectively without an instructor. Nor does it imply that a computer is a necessary management component, or that the course must be restricted to content required by the objectives. The purpose of the model, as stated earlier, is to produce--through a series of iterations--a course that has a highly predictable result, in terms of a previously specified minimum level of performance capability. Individualization is a possibility, as are packaging and computer management. The desired outputs should be identified as objectives, but there are no necessary restrictions on the course structure, format, or supplementary content.

There are certain ingredients of the empirical model that are common to all implementation methods and structures. The minimum components are: terminal performance specifications (objectives, which in this model take the form of criterion tests), descriptive objectives which serve as guides for the students, information study materials, diagnostic and progress evaluation tests, and sources of remedial instruction. The structure of the model ties those ingredients together by *feedback* and *quality control*.

The model, as described here, is the implementation model in abbreviated form; that is, all specifications of procedures and methods are included, but at the level suited to individuals who have already learned the skills necessary to implement the model. This version of the model includes the procedures, but not the instruction necessary to teach the implementation skills.

Fundamental to the empirical model concept is the notion that design of instruction should be an *experimental* process. Although all courses of instruction are designed on the basis of experience, logical analysis of purpose, intent, etc., many of them never proceed to any kind of data collection and revision. An experiment or a series of experiments have value only to the extent that data are used to verify or reject hypotheses regarding a series of judgments and resulting decisions. Basically, a course design is an experimental structure about which the designer says "This set of events, materials, methods, experiences, and procedures is appropriate, adequate and relevant, and will provide effective and efficient instruction of the students who are the target population." A nonempirical and noniterative procedure consists of simply implementing the course, *assuming* that the quoted statement was in fact correct, and then assigning all blame for inadequacies to the students themselves. The empirical course development model accepts the notion of *accountability* which attempts to remove all deficiencies, whatever their source, and to provide remedial instruction to insure that all students entering the course do in fact attain the objectives. Students are not relieved of responsibility for assigned activities, but the procedure is responsive to problems identified during and following instruction for two purposes: (a) to identify and remedy all deficiencies in student learning and (b) to modify the instructional system to prevent the deficiency from recurring. Purpose (a) is corrective, (b) is preventive.

The model described here includes procedures designed to accomplish both purposes. The fundamental structure of the model does not specify the form of instruction that is to be included--all available options remain open: lectures, demonstrations, discussions, laboratory activities, textbooks, programmed text materials, audiovisual materials, audio-tutorial materials, etc. The model does provide a series of procedures, with options, necessary to implement an empirical, iterative course development process. The model can be utilized for many purposes at many levels of course design and development: curriculum development projects at all levels of education, academic or vocational, for use in one or many schools.

Because school budgets fluctuate sharply from time to time as local and outside sources of project funds shrink and expand, many schools would find it difficult or impossible to assign a full-time staff to a project for course development utilizing this model. A larger, part-time staff can implement the model by assigning teams to activities that would ordinarily require a smaller number of individuals on a full-time basis. The basic model remains the same, but its method of application must be practical and feasible within existing staffing constraints.

This descriptive version of the model was developed as a series of procedural guides. These are step-by-step descriptions of activities to be performed. The advantage of the use of procedural guides is that the amount of background knowledge required can be minimized; users do not have to learn and remember every step in the procedures because the guides are always available for reference.

## PHASE I:
## IDENTIFICATION AND STRUCTURING OF THE COURSE OBJECTIVES

### PART A: OVERVIEW OF PHASE I

The delineation of the content and level limits of the initial course followed the methodology that was most common in the field of instructional technology at the time. Two basic levels of measurable behavioral objectives (MBOs) were identified: terminal objectives (TOs) which are relatively "large behaviors" of the sort that should be part of the student's repertoire at the end of the course; and the enabling objectives OEOs), which have also been referred to as *interim* objectives--the objectives that are not necessarily themselves part of the terminal objectives, but which must be learned by the student to enable him to attain a TO. This structure is more complicated than it needs to be. It posed a number of complex analysis, identification, and communication problems that were later found to be unnecessary.

Many people involved in work on instructional objectives have come to agree with Evans (1968), who, at an Aerospace Education Foundation and Office of Education-sponsored conference stated:

> ...I submit that a properly constructed criterion test constitutes both the necessary and sufficient conditions for accomplishing what we deluded ourselves into thinking we were accomplishing in the days of old when we tried to write behavioral objectives...The posttest is the ultimate operational measure of what you are trying to teach.

The final version of the model resulting from this project utilizes the criterion test as the basic design document which identifies the terminal behavior in a clearer form than is provided by *descriptive* objectives. The purpose, content, and value of the criterion test is the same as that sought through the use of descriptive objectives, that is, detailed specifications of the desired course output, in terms of student capability and competence.

Throughout this document, reference will be made to the course objectives, and to criterion test items. The statement above does not imply that objectives have no place in the model. The value and importance of the criterion test was stressed because it is felt that *objectives* have been overstressed in recent years and that the *criterion test* has not received the attention that it deserves. Most recent publications describing instructional technology, programmed instruction, applied accountability in education, and other empirical processes, have stated that instructional objectives are prepared first, defining the course and the more general goals of instruction. These sources then identify the criterion test as the second set of specifications to be prepared, indicating the form and method by which objectives are to be measured. The contention here, based upon the experience with the Naval Academy project, is that the criterion test should come first, and that it is the most important and most relevant course design document and set of specifications. Objectives are prepared later, primarily as guides for the students. The instructional design value of the descriptive objectives is secondary to their information value for students. After the student descriptive versions of the objectives have been prepared, they may be used to complement the criterion test and provide additional specifications for the course developers. The first phase of activities consists almost entirely of the development of terminal specifications in the form of criterion test items. The objectives prepared for student use are prepared later, as a part of Phase II.

The preparation of a final examination in most conventional courses of instruction is *not* the first step in the development of a course. The selection, sequencing, and presentation decisions regarding content are usually done first while the examinations are normally prepared much later. Sometimes, in extreme cases, the tests are prepared only after the instructor has had the opportunity to teach much of the course in order to decide what should be tested. In this model the criterion test is prepared first to provide the course developer with a set of specific, detailed, complete descriptions of the finished products--the course "graduates"--that the course is to produce, in terms of observable, measurable competencies.

The empirical model described in this document was developed in a specific setting, to accomplish a specific purpose within that setting. The model does not include any of the techniques of "task analysis" that have proven to be so useful in identifying the necessary competencies a student or trainee needs to take away from a course of instruction with him. There are basically two ways to go about identifying the criterion test performance and related competencies that are needed by a student upon completion of any course. If the student is to be able to carry out certain actions and have the necessary verbal background knowledge to do so in a job performance setting, the *job performance requirements* can be identified through application of the procedures and techniques that make up task analysis. Or, if a student is to proceed to a series of additional courses that build on the output competencies of the course being developed, the *entry level requirements* of those courses can be determined by using a modified form of task analysis. In those settings there is an external criterion, described by Branson (1970) as an "ultimate" criterion, beyond the course itself and, typically, beyond the control of the course designers. For example, if an individual is to be prepared for a specific job or is to be taught a specific set of skills that are relevant to many jobs or subsequent studies, then, course evaluation may be accomplished by measuring his performance directly in those later settings.

Most academic courses, however, are designed with little attention to external or ultimate criteria. The criterion performance toward which students are to proceed is much more vaguely defined as "learning the content of course X." And the only criterion measure is the proximate or internal criterion--the final examination--which is under the control of the course developers and/or administrators.

One might expect that job oriented training, whether conducted in an institutional *or* plant setting, would rely heavily on ultimate criteria, and make use of proximate criteria only where it has been shown that they accurately predict ultimate criterion performance. This does not, however, turn out to be the case in a surprising number of training courses. Courses are developed with emphasis on content, a final examination is prepared, and the course developers pay little attention to ultimate criteria in designing the course and the tests, or as instruments for evaluating the course effectiveness or relevance!

The use of instructional objectives has offended many in education because of an unfortunate impression that an objective--an operational definition of an instructional intent--is incompatible with the descriptions of goals and purposes that have guided education for decades. For example, is it valid to conclude that if the objectives approach is accepted, it is no longer possible to talk about the kinds of knowledge, understanding, appreciation, sensitivity, and judgment that formerly characterized accepted definitions of educational purpose? Not at all. It is generally very useful to describe a subject or a curriculum in terms of knowledge, understanding, and appreciation. That is only a first step, however, since at that level statements do not help to make instructional decisions. Those involved in working with instructional objectives have referred to those broad statements of purpose as "educational goals." Those goals help in taking the next step: expressing those goals in terms of operational definitions of the behavior that they subsume. For example, what should a student be able to do to indicate that he understands a specific principle? How does he manifest or demonstrate that knowledge? If he knows or understands "something," he should be able to do something with that knowledge or understanding, something that he could not do prior to developing that knowledge. An instructional objective is simply a statement of the capability that we should be able to observe on the part of a student who "knows" compared to a student who does not "know."

In effect, the objectives approach asks for ways of looking for and identifying evidence that an educational goal has been achieved. Although it is easier to accept as a matter of faith the assumption that certain educational experiences develop understanding, appreciation, and insight, the use of instructional objectives provides a method of seeking evidence that the assumption is correct, and a method of empirically developing instruction to *make* that assumption correct. The addition of an empirical, operational approach to education should make more goals attainable.

## PART B: ABBREVIATED DESCRIPTIONS OF PROCEDURES

1. Prepare the first set of test items consisting of the questions you would like your students to be able to answer at the end of the course, problems they should be able to solve, and tasks they should be able to carry out. Use existing tests or reference materials for guidance, and develop and group items by chapters.

2. Review all test items. Add as necessary to develop saturated test.

3. Complex items testing knowledge or skill learned in more than one chapter should be identified as final exam items. Also, break them down into items testing each major component. Assign the component item to appropriate chapter.

4. Review chapter posttest items and identify those that need to be segmented as in 3 above. Identify completed version for final exam, then break down into components and assign components to chapters.

5. Enter items in table, identifying one-step, two-step, and multi-step questions. For each multi-step item, write test item for each step, enter in table. Chapter 1 only.

6. Complete the table for all of chapter one. Repeat earlier steps as necessary.

7. Review all test items. Identify minimum "must know" items. Remove "nice to know" items and add to "enrichment" folder. Add to minimum set of "must know" items as necessary.

8. Complete steps 5, 6, and 7 for chapter 2 only.

9. Identify all technical terms required for chapter 1. Prepare definition or explanation question for each.

10. Prepare incorrect answers to all questions for use in discrimination training.

11. Review all items. If minimum level not completely covered, add or revise.

12. Meet with teammate, if team operation, and combine materials.

13. Cluster items by convenient topics, identify more complex items for final examination and component items for posttests.

14. Order items to reflect teaching sequence.

15. Write summary information and identify references for each topic.

16. Meet with teammate, combine materials.

17. Complete steps 5, 6, and 7 for chapter 3.

18. Complete steps 9 through 16 for chapter 2, as you did for chapter 1. Then do steps 17 and 18 for next chapters and repeat through all chapters

19. Refer to all materials and prepare saturated final examination. Review and see that minimum acceptable level is adequately reflected in test.

20. End of first phase.

## PART C: DETAILED PROCEDURAL STEPS

1. Collect or prepare a set of test items that test the kinds of behavior that you want your students to display, remembering that you are not at this time planning to administer this test. The test items should be of three types: first, questions that you want the students to answer (do not write them as multiple-choice items at this time, and convert all multiple-choice items to direct questions); second, problems that the students should be able to solve (stated as direct problems); third, tasks that you want them to be able to carry out. An objective is simply a *description* of the action that each question requires. At this point, do not write those descriptions; your test items themselves will do. This is your first version of the course design, in terms of the desired output.

2. Proceed through your text and the other reference materials you plan to use for the course (if that decision has already been made). Group your test items by chapters, topics, and related "knowledge." Examine the test items in relation to the content of the references: do you have a test item for *every single thing* that you want the students to learn? At this point you want to be certain that everything that they are to learn is reflected in the test--it should be saturated and comprehensive. Prepare additional test items as needed.

3. You will find that many of the test items do not readily fit into one of the chapters because they test a combination of knowledge and skills learned in several chapters. Examine these items; do not eliminate them. Identify them as final exam items, but at this point dissect them into the components that can be related to specific chapters. Add the new items to the chapter tests.

4. Review the test items that you have assembled for each chapter, and identify those that should also appear in the final examination.

5. Now start with chapter one and its test items. We will call the test for chapter one a posttest. Examine the test items. For each test item, ask yourself this question: is this a direct simple answer (one step), or does it require recall or application of more than one "bit" of knowledge or skill? Enter each item in the following table:

| No. | Description of Item | 1 Step | 2 Step | More Than 2 |
|---|---|---|---|---|

Each item that contains 2 steps or more should have the components identified. Unless each component is already in the students' repertoires, it will have to be taught and should be reflected in test items. Under each test item that involves more than one step, add an item that tests each component. Add these to your set of test items for that chapter.

6. This exercise may appear to be over-emphasizing test items, but you will find that these are the most useful guides that you prepare. You may never use some of these test items for actual testing, but they will help you design the course, and items that are not used on tests can be used as part of the study materials, for practice exercises, etc. Complete the table for chapter one.

7. Examine the table and set of test items for chapter one. Whether you are going to prepare self-instructional materials, group presentations, or some form of supplementary study material, the complete set of test items should identify the *minimum* performance capability that you feel every student should attain. Many will learn at least these items. Examine your test items. Do you find any that are not essential at the minimum level that you would like all students to attain? Are any based more on "enrichment," or content that is not critical? Try to identify any items that are more "nice to know" than "must" or "should" know. Use a red pen to check the unnecessary items in your table, and from your file of chapter one items, remove the "nice to know" items and put them in a separate folder labeled "Chapter One, Enrichment Questions." Examine the items again, and ask whether all "must know" objectives of instruction are reflected in your minimum set. Add additional items if necessary. If at any time as you review and examine, you feel that something is missing or poorly done, you can redo it, adding or deleting in order to keep the work on target.

8. Repeat steps 5, 6, and 7 for chapter two. Do not go beyond chapter two. We will always want to work with two chapters at a time, but we will concentrate on chapter one, looking at chapter two to be sure that whatever is needed for chapter two (prerequisites) supposedly learned in chapter one, actually is learned in the previous chapter.

9. Examine your test item table for chapter one again. Carry out the following steps for each test item:

   a. Ask yourself what technical terms the student has to learn in order to answer the question. List them. A technical term might be a name of an object or device, or the name of an event, procedure, consequence, principle, or concept.

   b. Many technical terms also have related definitions, descriptions, and explanations that are meaningless to students until they have learned the interconnections. Each can be described, defined, and explained at a different level of complexity. For each word or term, describe the *lowest* level answer that you want the students to learn in answer to the question, "What does this word (term) mean?" Add each of the definition or explanation questions to your list of questions.

10. The students must also be able to distinguish between correct definitions, descriptions, explanations, actions, etc. and those that appear similar but are incorrect. You must teach the discriminations. For each question, provide at least two examples of answers that look almost right or which represent a common misinterpretation or high probability error. Do this for chapter one only.

11. Your list of questions will now be lengthier than anticipated. This is as it should be. The purpose of a course is to change the capability of a student. The course content can be viewed from the standpoint of the questions that it is designed to answer or is capable of answering. That is the purpose of our present labors. Although considerable time is required, this procedure is the largest single activity making up the empirical model. Review all of your items with this in mind: *If a student, upon completing chapter one, could do all of the things covered by your set of questions and nothing more, would you consider him competent at that conceptual minimum level?* Again, add or delete as you think necessary.

12. At this point, it is advisable to consult with at least one other subject matter expert. This individual should also have experience with the subject matter and with the same type of students for whom you are preparing your course. He should also have completed the orientation and instructional materials contained in Phase I of this model. Ask him to review your set of test items, and give him a sheet of paper with these queries on top: "If a student--yours or someone else's--were able to answer all of these questions, solve all of these problems, and carry out all of these tasks correctly, would

you consider him to have learned everything that he should have from this part of the instruction? If not, what additional questions should be asked? Please write any additional questions or topics to be covered on this sheet. Are any of these questions ambiguous? Is it perfectly clear to you what an acceptable answer should be? If not, write the number of the questions on this sheet, with a question mark beside it." Let him review the items independently. Then go over the sheet with him. It is unlikely that your first version will be completely acceptable. If he can find no fault with it and can suggest no improvements, he is being too kind and not very helpful. Tell him so, and ask for suggestions and criticisms. Expect to have disagreements, and some arguments. Don't let that bother you. The two of you must help each other. He should have completed the same task for the same materials, and you will have to review his material. Between the two, working separately and then as a team, you should be able to combine materials and have an adequate working document for posttest one.

13. Consider each test item to be an objective. Do not become involved in the unnecessary procedure of identifying objectives. The terminology and process of structuring objectives in these forms is not worth the time that it takes and tends to confuse rather than clarify. It is useful, however, to cluster items that test the same principle, concept, fact, or process. Part of this has already been accomplished in the table that you prepared, in the definitions and explanations, and in the steps involved in each clarification of a major test item. You should group them because these clusters should generally be taught simultaneously or in sequence. The test items that apply to complex knowledge and skills should be largely reserved for the final examination although they may also be used in chapter posttests. It would not make sense, however, to test complex behavior on a posttest and then test less of it on the final. Review your items to be sure that the posttests test the components and appropriate large pieces, and that the final exam items test only more complex behaviors. Adjust the placement of items as necessary.

14. The scheduling of topics is usually surprisingly flexible. Unless a fixed sequence forces itself upon you as it would, for example, in a logical mathematical development, you need not become extensively involved in developing a logical sequence. You can follow the sequence used by standard textbooks, reference materials or a sequence that from your own experience seems easiest for your students. Develop the sequence of test items that you plan to follow in teaching. The stage of development in which we are now involved is that

of arranging a base of information that will help us make instructional decisions. The instructional objectives which in this approach take the form of test items, are the starting point. Now we want to use them to help us make sequencing decisions. We do that by sequencing the items themselves. Do it now, in an order that appears convenient and plausible.

15. Look at each major cluster of items--those having to do with a single, manageable topic. You now need to write a brief paragraph of general information about the topic, the kind of summary information that you can expand on later to provide the information that will help the student learn to answer those questions. Along with your own paragraph, identify choice selections from textbooks and other reference materials that discuss the topics. You should produce at least one double-spaced page of information and references for each manageable topic.

16. Now before you leave chapter one to do the same for each of the other chapters, meet with the other subject matter expert again and look at each other's collection of material and the test items that those materials support. Rework both sets until you have a combined package on which the two of you agree. Again, don't expect this to be accomplished without much discussion. Refer to other texts and other subject matter experts, if necessary, until you arrive at a mutually acceptable consensus.

17. Now take up the set of items for chapter two. Do steps 5, 6, and 7 for chapter three, keeping in mind that that is where the student must go and for which he must be prepared by chapter two.

18. Now do steps 9 through 16 for chapter two as you did for chapter one. Then do steps 17 and 18 for the next chapters, and so on through all chapters.

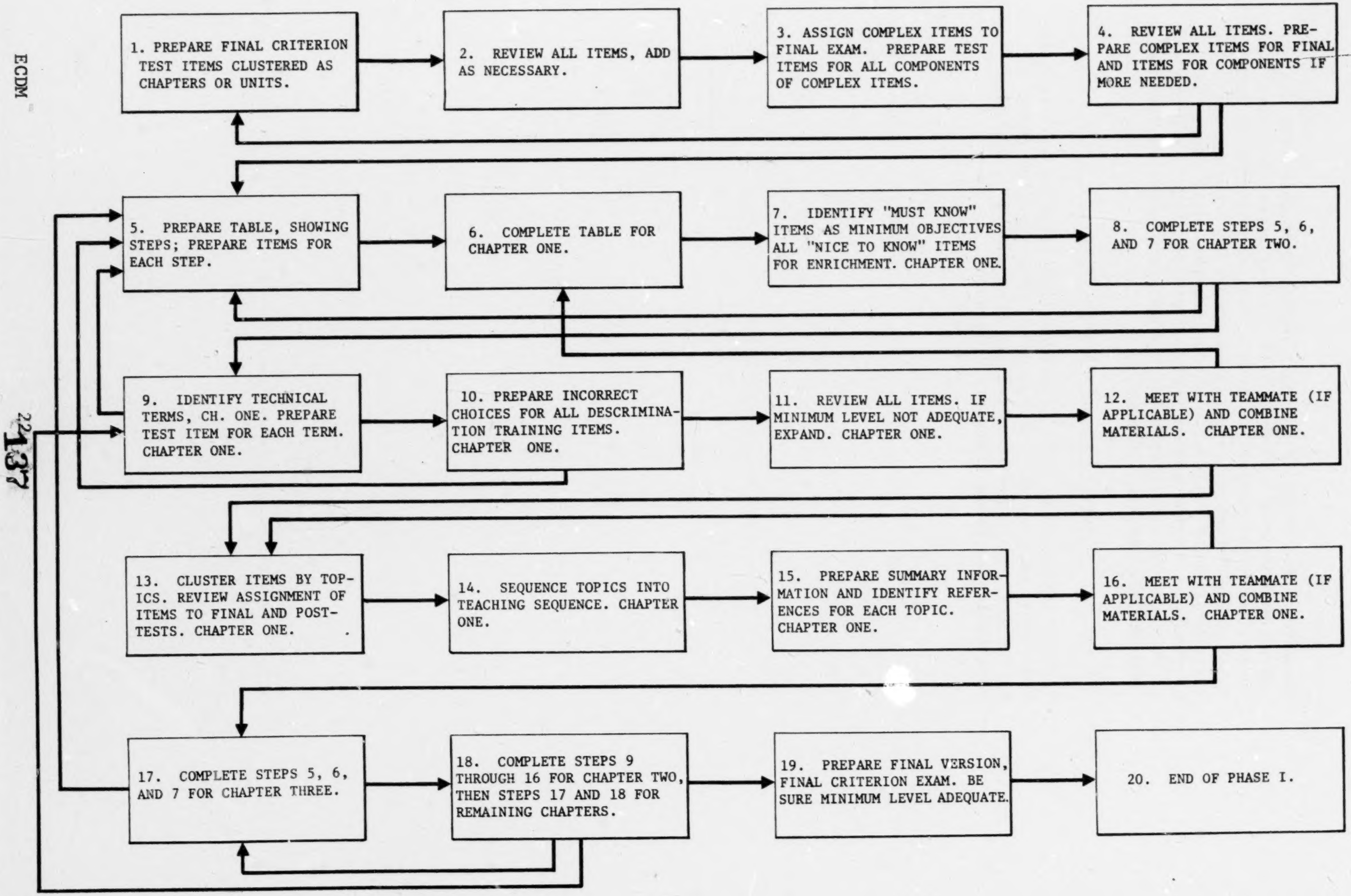
19. After you have completed the work on all posttests and the first cut of the related information, it is time to prepare a saturated final examination from the first version you prepared some time ago, adding to it by examining the posttests to be sure that you haven't overlooked anything. Don't worry about the length of this test; it may never be administered to the students. But it should reflect and clarify the entire set of terminal capabilities--at least the measurable ones. You may well feel that there are other important things that you and your course accomplish but which cannot be measured. If this is true, and you simply cannot find any way to measure them, forget about them for the time being; what we are concerned with here is identifying all of the measurable outcomes that you want to aim for and accomplish. Remember that we are going to establish a *minimum* set of competencies for *all* of our

students. The brighter and more highly motivated ones will go beyond the minimum. We will talk further about providing for them. But first we have to insure that the minimum is taught to all. Too often we casually do things in the interest of enrichment while failing to accomplish the basic course requirements. Revise and expand your present final examination to be sure that it is actually a complete picture of the minimum performance requirements.

20. Now you have completed the first major step.

Certain consequences will affect earlier steps or will require that those earlier steps be re-done. See the flow chart in Part D for the suggested recycling that should be done systematically as these steps are completed.

# PHASE I PART D


1. PREPARE FINAL CRITERION TEST ITEMS CLUSTERED AS CHAPTERS OR UNITS.

2. REVIEW ALL ITEMS, ADD AS NECESSARY.

3. ASSIGN COMPLEX ITEMS TO FINAL EXAM. PREPARE TEST ITEMS FOR ALL COMPONENTS OF COMPLEX ITEMS.

4. REVIEW ALL ITEMS. PREPARE COMPLEX ITEMS FOR FINAL AND ITEMS FOR COMPONENTS IF MORE NEEDED.

5. PREPARE TABLE, SHOWING STEPS; PREPARE ITEMS FOR EACH STEP.

6. COMPLETE TABLE FOR CHAPTER ONE.

7. IDENTIFY "MUST KNOW" ITEMS AS MINIMUM OBJECTIVES ALL "NICE TO KNOW" ITEMS FOR ENRICHMENT. CHAPTER ONE.

8. COMPLETE STEPS 5, 6, AND 7 FOR CHAPTER TWO.

9. IDENTIFY TECHNICAL TERMS, CH. ONE. PREPARE TEST ITEM FOR EACH TERM. CHAPTER ONE.

10. PREPARE INCORRECT CHOICES FOR ALL DESCRIMINATION TRAINING ITEMS. CHAPTER ONE.

11. REVIEW ALL ITEMS. IF MINIMUM LEVEL NOT ADEQUATE, EXPAND. CHAPTER ONE.

12. MEET WITH TEAMMATE (IF APPLICABLE) AND COMBINE MATERIALS. CHAPTER ONE.

13. CLUSTER ITEMS BY TOPICS. REVIEW ASSIGNMENT OF ITEMS TO FINAL AND POST-TESTS. CHAPTER ONE.

14. SEQUENCE TOPICS INTO TEACHING SEQUENCE. CHAPTER ONE.

15. PREPARE SUMMARY INFORMATION AND IDENTIFY REFERENCES FOR EACH TOPIC. CHAPTER ONE.

16. MEET WITH TEAMMATE (IF APPLICABLE) AND COMBINE MATERIALS. CHAPTER ONE.

17. COMPLETE STEPS 5, 6, AND 7 FOR CHAPTER THREE.

18. COMPLETE STEPS 9 THROUGH 16 FOR CHAPTER TWO, THEN STEPS 17 AND 18 FOR REMAINING CHAPTERS.

19. PREPARE FINAL VERSION, FINAL CRITERION EXAM. BE SURE MINIMUM LEVEL ADEQUATE.

20. END OF PHASE I.

# PHASE II
# COURSE DESIGN

## PART A: OVERVIEW OF PHASE II

There are three primary items which must be developed regardless of the instructional methods or procedures that are to be employed. The first is a set of simplified instructional objectives. The second is a set of sample test items to show the students what form the evaluation will take at the end of the block of instruction. These two are derived directly from the criterion tests and posttests that have already been developed.

The main purpose of these two items is to define precisely the incremental increase in competence that the student must attain. The simplified objectives describe and clarify the course expectations for a block of instruction. The sample criterion test items provide a closer look at that competence and also serve as a self-evaluation. By reviewing the test items, the student can begin to dichotomize his own fund of knowledge into genuine development of competence on the one hand and probable difficulties on the other. This places him in a good position to determine exactly what kind of help he needs and where to seek it. He will also be able to determine just when he is ready for posttests.

The third item to be prepared is the outline of instructional materials, presentations, and media to be utilized. Vocational training and other instruction of this nature require equipment, specific reference materials, and furthermore demand the production of special forms and various other types of paper work. Practice exercises must be an integral part of such instruction. These must be designed to achieve relevant instructional objectives and to provide *orientation, familiarization,* and *exposure.*

If group classroom instruction is to be a major scheduled component of a course developed according to the model, the lesson plans should be prepared at this time. They should identify the information that is directly relevant to the basic objectives, and also to the enrichment objectives. If a conventional textbook or series of textbooks is to be utilized, the student assignments should be identified for each criterion text item or set of related items, and for each of the simplified objectives to be given to the students. The same should be done for additional text or reference materials to be used and for all other individual study materials that will be available to the students.

If audiovisual materials are to be used for required or optional presentations, the information contained in the materials should also be catalogued according to the objectives and test items to which it is related. This third course design component supplements the first two by identifying the sources and forms of information available to the students in order to facilitate their attainment of the objectives. This content index serves to identify resources that the course developer and implementer can use. The students as well can draw on the index for either initial or remedial instruction.

The three basic components described above can be structured into a detailed management system without additional components. This combination is generally referred to as "learner controlled instruction" (L.C.I.), Robert Mager (1962) first suggested that, "If you give the students the objectives, you might not need to do much else." This hypothesis was tested first by Mager and McCann (1961), and later by Deterline and Mager (1968), and others. This approach makes the student more independent of formally presented instruction so typical of other methodologies.

The primary requirements for an L.C.I. course are an adequate set of descriptive information for the student, relevant and saturated criterion test items, and a management system. The management system required to make L.C.I. work effectively is perhaps the most complex in terms of the responsibilities that it must successfully meet. Because management systems for other forms of instruction tend to be merely variations on the theme, this segment of the description will emphasize that type of management system.

Since the course of instruction is basically under the control of the student who is allowed to select his own sequence, route, and materials, it is imperative that the management system maintain constant contact with him. As difficulties appear and as students encounter problems of various kinds, the system must detect those problems both for remedial purposes and to identify weaknesses in the system for corrective purposes. Diagnostic tests (in the form of practice exercises, progress evaluations, and self-testing materials) should be administered frequently. The system must evaluate and be responsive to progress at all times. This methodology is quite different from programmed instruction in the sense that the student is not walked through the instructional material itself. It is similar to programmed instruction, however, in its dependence on objectives, progress evaluation, and--basic to all forms of the model--validation by the iterative, empirical revision process. L.C.I. might appear to be very much like conventional independent study in its basic approach, but the use of the empirical model with its objectives, progress evaluation, and management system, make L.C.I. far more predictable in outcome than the typical independent study course can hope to be.

The version of L.C.I. to be covered in the model requires that each student be assigned a "sponsor" or teacher who is accountable for the student's success. The sponsor serves several functions, including that of the tutor-consultant when either the student or the system indicates the need. The sponsor is also the manager of his group of assigned students. He provides the interface between the system and each of the students. Frequent self-tests are used by the student to determine when he is ready for a progress evaluation test. These self-scored self-tests must be turned in to the sponsor when the student reports for his progress evaluation test. The system must provide detailed diagnostic information relating to the descriptive objectives and criterion test questions. During the development of the system, the sponsor and student together select the scope of the remedial activities and later, after the system has become more detailed, remedial materials of many kinds can be assigned directly by a computer if desired.

The system, through the sponsor, must also keep track of the students in relation to the calendar. Review tests which also provide the opportunity for additional practice, progress evaluation, and diagnosis should be given at least once each week, and the results handled in the same fashion as the other progress evaluation tests.

The concept of "trouble topics" is an important one in this approach. Some material is more difficult to learn than others. Many of the more difficult topics--the trouble topics--can be identified during Phase I, as the criterion tests are developed. Most teachers know which topics are difficult to teach and difficult for their students to learn. Test item analysis data also indicate those test items and objectives on which student performance tends to be low (traditional norm-referenced test practices, particularly in attempting to approach a 50-50 discrimination level, will tend to obscure information of this sort in test data files). Trouble topics can be examined from several points of view in an attempt to determine the nature of the source of difficulties. Available programmed text materials may be advantageously used as packages for trouble topics.

The final output of this phase is the first test version of the course. If L.C.I. is the basic methodology, students working through the course actually test the objectives and management system. When other forms of instruction are to be used, the precise instructional output of each ingredient must be assessed and revisions made. The model includes a provision for developing the first test version of any course as an L.C.I. course, with revisions moving the course in the direction of the desired final product.

During this phase, if parallel tasks were prepared by two or more project staff members, as suggested in Phase I, they should now work together as a team.

## PART B: ABBREVIATED DESCRIPTIONS OF PROCEDURES

1. Develop descriptive objectives for use by the students. Add additional information about each objective in the form of an information panel.

2. Prepare sample test items or problems to give students along with objectives.

3. Review and revise.

4. Select instructional content, materials, and basic forms of study as described in the following six steps.

5. Learner-controlled instruction: identify, indicate sequence options, relate all materials to objectives and criterion test items.

6. For group lectures: use responsive lecture form; for conventional texts: identify paragraphs, pages, and sections related to each information panel. Consider self-pacing within weekly schedules.

7. Guided walk-through, or guided demonstration by students as alternative to instructor or AV demonstration: Include necessary directions and guidance.

8. Prepare programmed lesson plans for group interactive sessions; other interactive study materials as resources permit.

9. Select available programmed materials by matching objectives to course objectives. Review published data. Reject unless objectives and data are furnished.

10. Select audiovisual material for purposes of interest, clarification, relevance, enrichment, repetition, etc. Identify each presentation as to purpose, content and relevant objective(s).

11. Identify "trouble topics." Provide more detailed assistance for students for those topics.

12. End of second phase.

At the minimum material preparation level, the learner-controlled approach makes use of existing materials with little or no modification. A variety of interactive materials can be prepared if the course development project permits. A number of methods for the preparation of such materials are provided in the Appendix.

## PART C: DETAILED PROCEDURAL STEPS

1. The output of Phase I is a complete description of the course in the form of all test items that the students should be able to answer upon completion of the course. The final examination and the posttests indicate the level of competence expected at each progress evaluation point in the course. Now you must develop a set of objectives for the students to use; you must describe the terminal behavior for them in terms that will enable them to recognize each increment in progress and increased competence, and anticipate what is yet to come. These objectives must be technically accurate, of course, but they are to be written for the students, not for your peers; make them clear, simple and comprehensible. Later, during the testing phases of course development, you will determine just how clear, unambiguous, and informative these objectives are for the students. Do not become involved in attempting to apply some simple formula to the form of the objectives such as starting each statement with "you will be able to..." These objectives for the student should be informal descriptions, not lectures, of the kinds of problems or concepts that he will learn to work with and the kinds of situations about which questions will be asked. You might produce a page or two as a description of a single objective. Remember that you are trying to inform the student, telling him what is coming and what he will learn to *do*. You might label these descriptions "Information Panels" or "Introductory Information."

   The amount of information and number of objectives depend on the complexity of the objectives. Try to prepare an information panel for about a half-hour's work, whether it consists of one objective or ten. Try also to prepare the information in a meaningful package of content, adjusting the number of objectives (posttest items) so that the cluster makes sense and the objectives are closely and logically related to each other. Prepare a complete set of these descriptive statements for each chapter or unit leading up to a posttest.

2. Now we are back to test items: prepare some sample criterion test items to show the student what he will be able to do at the end of the study for each descriptive information cluster. Here again, do not attempt to force everything into the form of multiple choice items. Use direct questions, problems, and task descriptions. These sample items should parallel the posttest items for the chapter, but you can devise items that test larger amounts of behavior; that is, a sample item might be a large problem that requires the use of several kinds of skill and knowledge learned in the chapter, or a combination of new and old skills or knowledge. The purpose of these items is to allow the student to evaluate his own progress. He should be able to look at each item and attempt to answer it. If he can-

not, that means that more study is required. If he can, that should mean that he has learned and is ready to take the post-test for the purpose of progress evaluation and diagnosis.

3. Review the descriptive objectives and sample test items. Do they adequately define for the student where he is going, how to assess his own progress, and how to tell when he has attained the objectives? If they do not, revise them so that they do.

4. The materials that you have assembled provide the student entry information: the general set of items identifying for the student the progress that he is to make as he proceeds through each block of instructional information. These materials also provide the specifications of the terminal behavior capability and the instruments for assessing it. Now the content, instructional methods, materials, media, and events must be identified. There is an unlimited number of options available. The information contained in the information panels and sample criterion test items should enable the students, with additional help when necessary, to proceed through almost any form of instructional event or material, and attain the objectives. You could simply provide scheduled group lectures and a textbook in a conventional structure. But there are several disadvantages to that approach. To mention just a few: a lecture is not the most appropriate and efficient use of a teacher's or the students' time; scheduled group lectures are unnecessarily restrictive for both teacher and students; many students who could proceed much faster are held back by the group pace. Slower students generally need more time than is generally available for a lecture. A group discussion or orientation lecture to elaborate on the information panel, a demonstration, or an audiovisual presentation is often a desirable form of large group instruction. In any case, scheduled group lectures are among the options available, as are conventional textbooks, films, workbooks, reference books, library reference materials, programmed textbooks and laboratory manuals. At this point the first decision must be a choice between learner controlled instruction and interactive or guided walk-through forms of instruction. Identify the forms that you plan to use, singly or in combination, and complete the steps indicated:

   a. Individualized L.C.I. - step 5

   b. Group conventional instruction - step 6

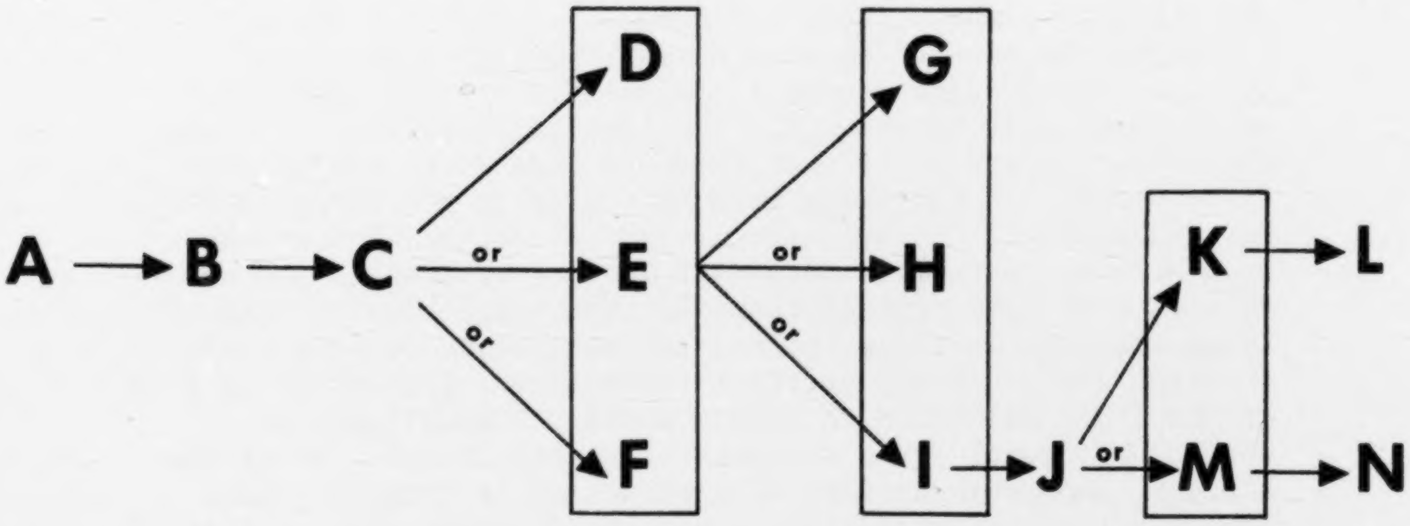
   c. Guided walk-through activities - step 7

   d. Interactive locally prepared instruction - step 8

   e. Programmed (published) instructional materials - step 9

   f. Audiovisual materials - step 10

5. The role of the instructor in L.C.I. is primarily that of consultant-tutor and manager. All reference materials must be chosen on the basis of their apparent clarity and assumed ability to facilitate the student's attainment of the objectives. A variety of books--technical, text, and popular reference materials--should be examined. For each information panel you should prepare a recommended reference list. It is advisable to identify top priority references--those that appear to be potentially the most effective and easiest for the students--and additional references covering the same information. Do so on the basis of smaller-than-chapter segments, identifying paragraphs to be read, omitted, skimmed, and so on. If there are audiovisual materials that are relevant, they should also be identified as either high-priority or supplementary. You should prepare a brief description of each item, identifying the content and related objectives. As you identify each relevant source, don't simply list page numbers in the referenced list; write a brief description of each reference--what is discussed, whether highly technical, popularized, applied or theoretical. You will be generating a single reference list for each information panel. At this point, review the *content* and *enrichment* you previously prepared to help your earlier decision making. If you decide to make these available to the students, they need to be edited, duplicated, and added to the resource lists. You should also consider that L.C.I. often offers the students an option in the sequence they follow through the objectives. Earlier we noted that unless a mandatory cumulative sequence is imposed on the course designer, there may be no single "best" sequence; in that case you might offer the student the option of scanning information panels and following any sequence he desires. You may find that there are some sequential constraints like those shown in this table:



Each letter represents an information panel and its cluster of objectives. Cluster A must come before B, which must come before C, and all three must precede the other objectives. After C has been completed, D, E, and F can be taken in any order, but all three must be completed before going on to the next group. G, H, and I can be taken in any order, but I must come before J, and J should immediately follow I. K and M can be taken in either order, but K must precede L, and M must precede N. You will be able to identify most of these relationships but you might not discover all of them. Students will identify them for you as they attempt sequences that do not work. You should provide students with a table similar to the example, pointing out their options and constraints.

In addition to the sample criterion test questions, problems, and tasks which provide initial information as well as self-test opportunities, you should consider including additional practice and progress evaluation problems. Their purpose is to provide the opportunity for needed practice, and to provide the students with an opportunity to determine their own progress and shortcomings. Avoid irrelevant or unnecessary busy-work. This combination of materials is about all that you need at this point; the next step--building a management system to make it all work--will come later.

6. Let's consider several components that are generally referred to as conventional instruction. The group lecture varies in many ways, ranging from a formal and nonstop presentation designed by the instructor with no input from the students, to a responsive presentation determined entirely by student input. A responsive lecture form should be used since the students, having studied the information panels, will be able to ask relevant questions and request information for specific purposes. Many students, given objectives toward which to work, are more aware of the information they need than is the instructor. If conventional lectures are to be given, live or taped, the lesson plans should be structured tightly around the objectives and information panels. (This does not preclude the use of enrichment and supplementary information of general interest, of course.) The number of such lectures should generally be reduced. They should be scheduled toward the end of each week so that students have more time to work individually and can bring problem topics to the group meetings for discussion. A conventional textbook or set of textbooks, or a primary text plus additional library references are used in a more or less typical fashion. You might consider identifying specific sections, pages, and paragraphs to facilitate locating the necessary critical information, perhaps along some of the lines discussed in step 5 above. Scheduling must be worked out, considering a number of possibilities. Since even a highly conventional form of instruction in this structure involves more individualized study, self-pacing will scatter

the students. This will disrupt any group-scheduled components unless provision is properly made for them. One possibility is the weekly scheduling of topics with posttests administered on a group basis at the end of each week. Group activities such as lectures and films might be scheduled for the entire group or segments of it. Laboratory sessions are best handled in small groups or individually. Students would be expected to move individually through the topic or topics for the week, but all must have reached the progress evaluation checkpoint no later than the time of the scheduled posttest. This method will allow the students to spread out within a week, but they will all reach every progress evaluation checkpoint at the same time, and all will start each new topic at the same time. This form of scheduling appears to be necessary if group topic lecture/discussion meetings are to be held for the entire group, or large subgroups of students. Other considerations will be in the management phase.

7. A "guided walk-through" is a process which uses a procedural step-by-step guide to carry out some process or activity. For example, a laboratory exercise may use a manual with detailed directions, an audio tape, or live guidance to provide those detailed directions. In a group setting the walk-through is easily guided by providing the necessary information, directions, and adequate time for every student to complete each step. If the steps are complex, students will tend to differ in the amount of time required; individualization will then offer many advantages. The purpose here is to provide students with relevant hands-on practice and experience. If the resources are available, allow it; this is often highly desirable and far more effective and interesting than a demonstration or explanation. Existing published manuals, workbooks, and programmed materials will often be usable for this purpose, sometimes requiring supplementary material to fit them to your environment. For individual use the "audio-tutorial" method used extensively at N.Y.I.T., offers a number of advantages. In this approach an audio tape is the controlling element, directing the student step-by-step through a laboratory or demonstration exercise, and to supplementary text material or other sources of information.

8. Locally prepared interactive instructional materials are specifically designed for use in a given course as opposed to commercially published materials. Group recitations lend themselves to interactive instruction. These interactive elements should be deliberately programmed into group lectures and teacher-directed discussion meetings. The programmed lesson plan is the principal ingredient of the interactive lecture or classroom tutorial. To prepare a

programmed lesson plan, the following steps are suggested:

a. Review the objectives (as listed for the students) and the posttest for a given lecture period. Review the information to be presented as a means of helping students attain those objectives.

b. Start with posttest item one and review again the objectives and lecture information assembled for that single test item. Decide on the form that student practice should assume to assure that the desired behavior as specified by the objective will result. In other words, given the objective, posttest item, and content information, ask, "For what purpose is *this* information presented in relation to the objective; what should the student be able to do after seeing or hearing this information as an increment in his capability as he moves toward the objective?" Identify a question that he should be able to answer, utilizing the information being presented, or a problem or task for which the information should prepare him. Structure the question to be asked during the classroom presentation.

c. Repeat for each posttest item. Some items might call for several classroom responses, others might require only one. The classroom responses should allow the student to practice relevant verbalization, interpret and apply the information being presented, and provide the opportunity for on-the-spot progress evaluation and diagnosis.

d. Review the entire list of response requirements. Is the set adequate and complete? Are the responses relevant to the objectives? The questions should differ from those used on the posttest to the extent that memorization on the part of the students becomes unprofitable.

e. Prepare some form of visual presentation of the requirements. You might set up projected visuals or flip charts. Convenience, practicality, and relevance of various media will be discussed in a later section.

f. If self-study materials of an interactive sort are to be prepared locally, the same methodology applies to adjunct programs and programmed materials.

9. There are many well-validated and effective programmed texts available from textbook publishers. These can be evaluated for use with any of the methods of instruction described above.

There are, however, several points to be considered:

a. Some publishers describe their programs as validated but have no objectives or data to support the claim. Unless both objectives and data are available, do not consider the use of a published program.

b. Obtain the objectives and review them to see how well they parallel the objectives and criterion test items that you have prepared. Incidentally, if at this time you encounter some objectives that you had not thought to include, but which now make sense to you and sound as though they should be added to your course, do so. You will not always find a perfect match between their objectives and yours. If the match is close, the program might be usable. If the published program contains objectives beyond your own, it may be that they can be omitted if such omission would not disrupt the sequence and cause the program to break down. It may be that you can refer the students to other materials or supplementary instruction, or to objectives that are missing in the published program. Examine the data. Does the program appear to work reasonably well--say, at least 80% of the students appearing to achieve 80% of the objectives? For weaker sections of the program, can you provide some convenient form of supplementary work to improve the package? If there are enough advantages, consider adding the program as an instructional component. You might consider using the programmed materials for remedial instruction rather than the initial instruction if a faster method seems to be available for some of the more capable students.

10. Audiovisual segments of various kinds can also be selected or locally prepared for inclusion in your set of instructional materials. First of all, there is evidence that students rate audiovisual presentations such as motion pictures and videotapes quite favorably even though the materials might have no measurable effect on learning. The student has an opportunity to observe what he has been reading about and hearing about. Furthermore, the audiovisual inputs are often a welcome change of pace. These points should not be rejected as irrelevant to the task of achieving the objectives. Student interest and affective reactions to the total course are quite important and often critical. There are other considerations such as clarification, redundancy and repetition in an alternate form. If a complex process, operation, or device has visual features that must be comprehended by a student, and if verbal descriptions are complicated and easily misinterpreted, audiovisual materials then have real value.

In the list of resources given to the students all audiovisual materials should be identified as to purpose and content. Those that present information directly tied to objectives should be identified together with corresponding objectives. An entry should also be made in the list of resources for each objective so that a film relevant to a particular objective is indicated as such, with the title of the film and a note to see the description. This may be obvious, but in most courses AV materials are used only once and are then unavailable for student review. Be sure that the materials are made readily obtainable so that the students can use them individually as often as they like. This might involve some training in the operation of special purpose equipment or operators might have to be present at specified times, but if the AV is a really good item it will be worth the effort.

One should not assume that the visual quality and production elegance of an audiovisual production is necessarily an indication of instructional effectiveness. Although these are often called instructional materials, most are presentations of information and are quite variable in their instructional outcomes. It will help if a brief test or set of problems is prepared for each AV and given to the student prior to viewing. The directions to the student should point out that the posttest items indicate the objective(s) or purpose(s) for which the AV items is made available. Here again, by reviewing the test items prior to viewing the AV material, the student will be better able to focus on the critical content of the audiovisual. This is not necessary for AV materials that are used only for enrichment or overview purposes.

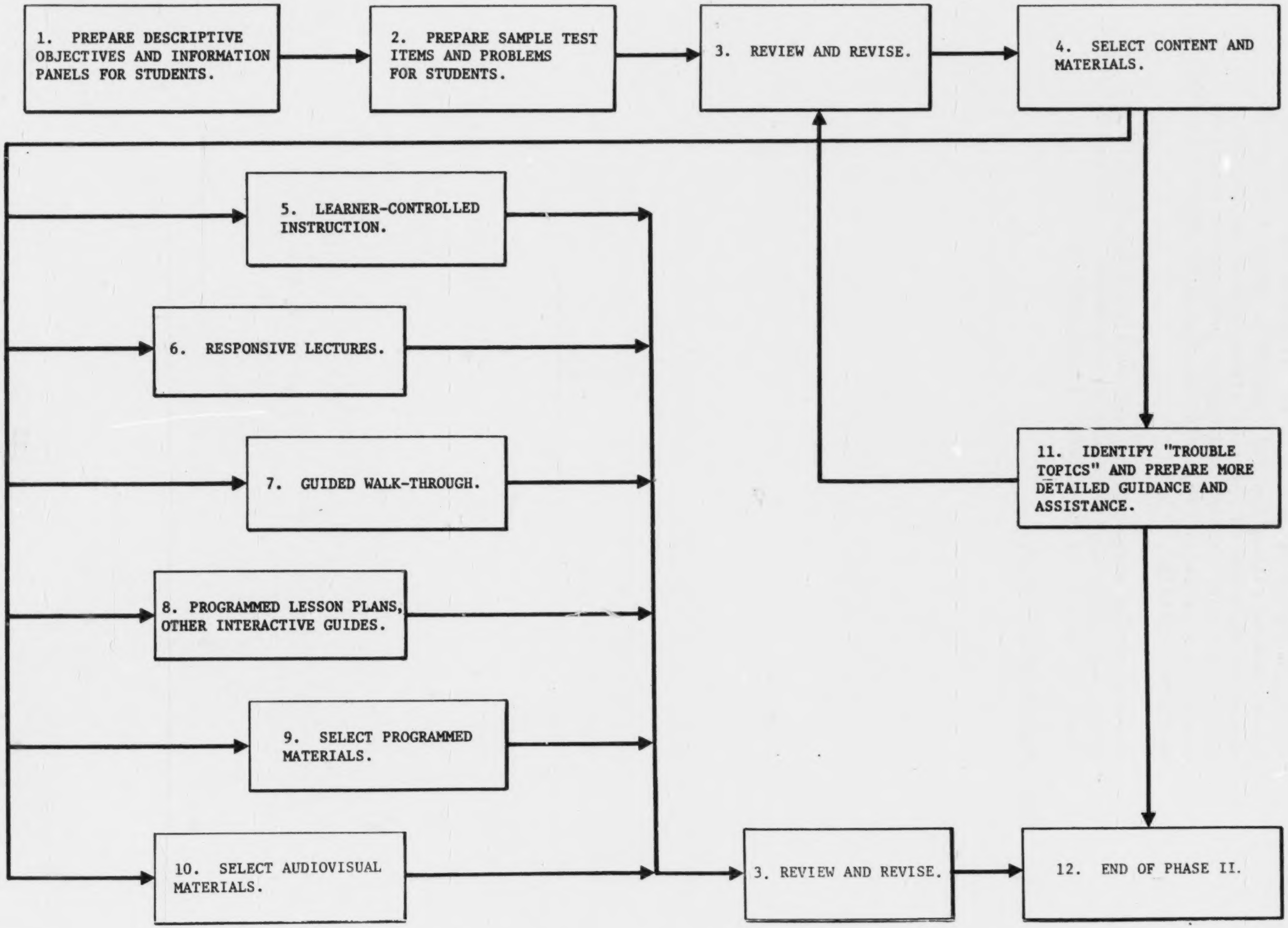
11. Combinations of all of the above approaches are possible. There is no data to indicate that any approach should automatically be rejected. This first-cut version of the course need not, and will not, be perfect the first time around. The next step in the process is initial developmental testing, the purpose of which is to identify the most critical deficiencies and correct them. Additional developmental testing will then further improve the course and the related management system.

One more step remains to be taken before the management system for developmental testing is designed. All courses contain some objectives that are relatively more difficult than the bulk of the other objectives in the course. These are related to the trouble topics mentioned previously. Trouble topics can be anticipated by most teachers who have had previous experience with a course and with the same type of students over several years. Both local and standardized test results will also identify those that probably fall into the trouble topic category. You should provide additional assistance for your students for those topics. Special media, programmed materials, simplified practice materials, and other supplementary materials should be available for students for these topics. Later, during evaluation and diagnosis, special attention should be directed to the test items related to trouble topics, and more intense and highly interactive remedials should be available. This will be discussed further in the management section.

Certain consequences will affect earlier steps or will require that those earlier steps be reexamined. See the flow chart in Part D for recycling recommendations.

12. End of second phase.

# PHASE II PART D


1. PREPARE DESCRIPTIVE OBJECTIVES AND INFORMATION PANELS FOR STUDENTS.
2. PREPARE SAMPLE TEST ITEMS AND PROBLEMS FOR STUDENTS.
3. REVIEW AND REVISE.
4. SELECT CONTENT AND MATERIALS.
5. LEARNER-CONTROLLED INSTRUCTION.
6. RESPONSIVE LECTURES.
7. GUIDED WALK-THROUGH.
8. PROGRAMMED LESSON PLANS, OTHER INTERACTIVE GUIDES.
9. SELECT PROGRAMMED MATERIALS.
10. SELECT AUDIOVISUAL MATERIALS.
11. IDENTIFY "TROUBLE TOPICS" AND PREPARE MORE DETAILED GUIDANCE AND ASSISTANCE.
3. REVIEW AND REVISE.
12. END OF PHASE II.

## PHASE III
## COURSE MANAGEMENT AND MAINTENANCE

### PART A: OVERVIEW OF PHASE III

Although widely used, the term "management" as applied to educational technology is perhaps unfortunate. Scheduling of events, materials, and resources are a small part of it, yet this simple interpretation is sometimes found in the literature. In an accountability setting the management activities also include all of the procedures involved in following the students and responding to them as they proceed through the course. If a student encounters difficulty, *and cannot recognize that fact,* he is not in a position to seek assistance or to take independent remedial action. One component of the management system, not monitored or implemented by an instructor or other administrative person assigned to the course, is a set of materials that provides for student self-evaluation. These include practice exercises or problems, self-tests, and other similar materials. They are added to increase the likelihood that problems will be identified as soon as possible after they develop. The objectives and sample criterion test items also assist the students in making discriminations of this nature.

Frequent criterion tests are required of each student on a student-scheduled basis, a system-scheduled basis, or both. The tests serve several purposes: the students know precisely the behavior to be tested and work toward the requirements of the tests; the tests provide additional practice of the desired behavior; the tests provide direct evidence of progress toward the objectives for both the students and the system. The tests serve a diagnostic function--identifying problems, deficiencies and misinterpretations for both the students and the system.

Different management requirements exist for free-running courses and for scheduled courses. While many requirements are common to both scheduling structures, each demands special materials, methods, and procedures unique to that form of scheduling. A scheduled course, as noted earlier, has certain advantages over a free-running course from the point of view of the management system. Resources, meetings, and reusable materials (such as audiovisual materials) are more conveniently scheduled and controlled. The position of each student in the course is always relatively closely identifiable. Group scheduling, however, does give rise to certain difficulties. For example, if assignments are given to all students for a week's work to be followed by a group posttest at the end of the week, every student will have to have finished the necessary work in order to be prepared for the posttest. Sometimes the amount of time required to reach a set of objectives is grossly underestimated by the course development staff. In that case the students may find it difficult to meet all requirements in the available time. Such time misallocations will be identified during early testing of the course and later adjustments can be made. In the meantime the management system must be designed to be sensitive to such problems so that they can be identified on the spot, and schedule modifications made as necessary.

A free-running course is flexible enough to allow for contraction and expansion of the time requirements for units of study and sets of objectives. But there are many other kinds of management problems that may arise. These must be anticipated. If, for example, all students are to meet with an instructor when they have successfully completed, say, unit ten, then the management system must maintain detailed records of progress so that as students near the end of unit ten they and their instructor can be scheduled for such a meeting. Audiovisual materials that all students will eventually have to use must be scheduled or made available at all times (e.g., in a library or learning center). Students entering their first independent study course have little skill at adjusting their pace, even when only one free-running course is involved. If they are concurrently taking several free-running courses, and have no schedule or dated checkpoints imposed on them, they tend to concentrate on certain courses and lag behind in others. The management system must insure that schedules are in some way adjusted so that *all* students will have met *all* completion requirements by the established deadlines or latest possible dates. A great deal of flexibility is possible. There is no need for a student taking several free-running courses to progress in equivalent increments in all courses at once. But for each course a slowest possible completion schedule must be established, and all students must be prevented from falling behind that schedule.

The two principal problems that students will first encounter involve initial comprehension, and retention. Lack of comprehension is the more difficult problem (obviously there is nothing to retain if comprehension has not occurred), but a variety of options are available to test initial comprehension and identify deficiencies. Practice exercises, frequent tests and review exercises can be inserted as necessary. The data accumulated by the system will quickly identify student needs. The management system must signal deviations and deficiencies, provide feedback information, and provide appropriate forms of remedial instruction or sources of corrective information *as quickly as possible* after the need is identified. The development of materials requiring overt responses in the form of programmed books, practice exercises, workbooks, and sub-tests is essential. Although some of these materials may be identified as necessary *instructional* items, others will have to be added as management ingredients to provide the management system with the necessary student performance data at frequent intervals. It may be decided, for example, that for generalization and retention purposes a set of practice exercises is necessary for a given unit. The exercises might then be scheduled late in the sequence for that unit, just before the posttest. The management system, however, might require performance data much earlier, particularly if tryout data indicate that comprehension is highly variable. This would also be true if the unit consists of many trouble topics and students are having difficulty with the initial portion of the unit. One option is the addition of programmed materials for smaller step progress; another is the inclusion of practice problems, sub-tests, or other tasks requiring overt responses that can be evaluated immediately by the system so that corrective action can be taken. Different philosophies of learning are involved here, but the options made available to the system should be practical and cover a broad range unless data indicate that there is a single best way.

The key to making accountability work in any form of instruction is the effectiveness of its progress evaluation, diagnostic, and remedial functions. The iterative methodology of the model is necessary because all three of these components must be developed empirically; there is no adequate approach--technological, logical, or intuitive--that can develop an adequate evaluation, diagnostic, and remedial system on a one-try basis. The experimental approach is essential.

The management system must provide for data collection in a usable form together with appropriate and practical methods of analysis. This data must be collected and analyzed on a student-by-student and objective-by-objective basis. Few bases for instructional decisions are provided by group averages or group indices of course effectiveness. Test results must be evaluated in terms of objectives as well as test items. Most objectives will be tested by more than one test item. Many invalid conclusions have been drawn in the development of programmed materials as a result of ignoring the item-by-item, objective-by-objective, and student-by-student view of the data. The management system must include the necessary data analysis and interpretation methods. For example, a single posttest provides data of several kinds: *each* test item elicits a response from *each* student, a response that can be compared to the desired response. The single response is far more important than a number indicating the percentage of students responding correctly. A single response can be studied to identify the precise nature of the deficiency so that specific corrective action can be taken. The nature of standardized, objective testing is generally highly impersonal, with the responses reduced to marks on answer sheets. For norm-referenced testing this approach is very advantageous, but for formative criterion testing the very data most needed for corrective revision purposes is eliminated. For our purposes it is not enough to know that a student missed an item and its related objective; it is necessary to find out *why* he missed the item, and whether the fault lies with the student or the item itself. Students should be interviewed formally or informally to determine why the response was given and what thinking sequence led from problem to solution.

A student, given two test items presumably testing the same objective or same components of an objective, will sometimes respond correctly to one and incorrectly to the other. Interviewing the student is probably the most direct way to locate the source of the difficulty.

## PART B: ABBREVIATED DESCRIPTIONS OF PROCEDURES

### Section One: Management of Course Implementation

1. Assemble all materials for each chapter. Review all materials for chapter or unit one.

2. Review posttest for chapter one in relation to objectives and content. Revise posttest if it appears necessary.

3. Review sample test items in relation to posttest. Do the sample items adequately indicate what kinds of competence will be required by the posttest? If not, revise and expand the sample items as necessary.

4. Prepare a student self-evaluation test requiring the same knowledge and skill required by the posttest and illustrated by the sample items. Obviously the items should not be identical, but should test the same competencies. Repeat steps 2, 3, and 4 for all other units or chapters of the course.

5. Prepare general directions for the students and add it to the package of information materials that each student is to receive (objectives, sample test items, information panels, resources keyed to objectives, etc.). This list should include the location and method of obtaining all materials, schedules, location of audiovisual and other special materials and method of scheduling meetings with sponsor. Prepare instructions for self-testing using the sample items and practice exercises. Provide self-scoring method and material; scoring should *discuss* correct answer, not simply indicate it. Identify remedial options or prescriptions. Identify trouble topics and the additional materials provided to facilitate study. Specify what materials are to be handed in and the procedures for doing so. Indicate method of providing immediate evaluation and diagnostic information.

6. Review directions and assess adequacy. Revise and expand if that appears necessary.

7. Prepare description of standard format to be used for all sets of directions and supporting information. Use standard table of contents as far as possible. Review all materials and revise to conform to standard.

8. Review each package (unit, chapter) and review schedule, for minimum completion pace. Revise scope of each unit if necessary.

9. If possible, have small group of test students examine the first package of information and directions to determine clarity and comprehensibility. Collect comments, opinions, suggestions.

10. Review all information, revise if appropriate.

11. Identify first test group of students, small if possible. Obtain necessary number of instructors and managers for number of test students. Arrange schedule and staffing assignments.

12. Develop the test scoring and feedback methods for getting results to students and sponsors.

13. Develop procedures for conducting oral examinations for small groups of students for each posttest.

14. Develop the "housekeeping" management checklist. This should include among other things, arrangements for obtaining and issuing necessary texts and other materials that all students are to be given including the packages of information and directions; identify other materials and see to their procurement and filing; develop procedures for student submission of materials, specify who is to collect them, where, etc. Establish procedures for administering posttests. Prepare record forms for student comments, time records if possible, lists of resources used, and so on, so that as complete a record will be obtained as possible. Prepare forms for instructors to record all relevant information. Prepare orientation for the students, to describe the course, resources, materials, and the management system to the extent that they need to know about it. Assign instructors as sponsors and prepare list of procedural guides for them to follow. Prepare form for instructors to use to record any suggestions--at the time the suggestions occur to them--about course or management revisions. Consider the possibility of using validated programmed text materials for additional assistance for slower students or for remedial instruction.

15. Prepare indoctrination workshop for all instructors and other staff members who will be involved with management, data collection, or any other aspect of the course. The workshop must teach them all skills that they will need in order to do their parts of the total task.

16. Develop the complete set of procedures, including use of the computer, for test scoring, evaluation, diagnostics and remedial assignments.

17. If you plan to make any experimental comparisons of materials, methods, media, etc., develop the experimental designs and data collection instruments. Develop all implementation procedures to conform to the experimental and management requirements of the course.

18. Prepare scoring keys for constructed response-type test items (essay, sentence completion, problem-solving, task performance, etc.). Specify the minimum acceptable requirements for each objective. Indicate that the keys are to be used to evaluate responses, and to identify critical missing components or incorrect responses for later revision purposes.

19. Develop procedures for using the critical incident technique as a means of identifying and collecting descriptions of both positive and negative critical incidents. The method should be used by all staff members and by students, if feasible.

Section Two: Analysis of Results and Revision Decisions

1. Assemble all sets of information for convenient reference. Arrange to have a conventional items analysis performed on all final criterion test items.

2. Prepare a test item-by-student table for the final exam test items.

3. Prepare the master chart, listing each objective, its related final criterion test item(s), and the minimum acceptable answer for each item.

4. Use the table, the item analysis data, and the chart for reference. Identify all items answered correctly by more than 70% of the students. Ask instructors to review each of these items to determine validity.

5. Identify all items answered correctly by fewer than 30% of the students. Have instructors determine whether item appears too difficult, ambiguous, or incomplete.

6. Review decisions. Have another group evaluate same items, then discuss and arrive at concensus judgment.

7. Revise items identified as requiring revision in steps 4, 5, and 6.

8. Review revised items in relation to objectives and related information. Make any needed revisions of the test items or the supporting, clarifying information.

9. Prepare a description summarizing the data for each remaining test item. List any questionable features, and identify special sources of information that need to be reviewed in order to decide whether an item requires revision. All other data that might answer a specific question about the item should be identified (e.g., the wrong answers given by students might indicate what was wrong with the item or with the instruction).

10. Analyze all test items not previously examined in steps 4, 5, and 6 above. The data summaries indicate the level of difficulty, but not whether the item is good or poor, or whether answers reflect on the item or the instruction. Make these judgments and indicate which items need to be revised. Prepare a Revised Criterion Test Master Sheet and enter on it all items that are to be used again in unrevised form plus the newly revised items. The numbering system on the Master Sheet should match that on the data summary sheet. Put a red check on each of the two forms beside each newly revised item.

11. Prepare similar sheet for the posttest items.

12. Review all posttest items in the same manner as for the final exam items and make necessary revisions. Prepare a Revised Posttest Master Sheet.

13. Starting with the unrevised final exam items, review all data and develop the revision specifications for each item, carrying out all steps described in the detailed procedural guidelines.

14. Evaluate the management system using all relevant information; specify the required modifications and revisions; complete the revisions.

15. Make the decision regarding the conversion of test items to a more readily-scorable form. Prepare the new items. Develop the procedures for testing the new set and comparing the results with those for the original set.

16. Review all materials and management procedures. Revise as necessary, and then make the necessary preparations for the second test tryout of the course. Follow the same procedures as before--or modified versions of them--for running the course and collecting the data.

## PART C: DETAILED PROCEDURAL STEPS

### Section One: Management of Course Implementation

1. There are two primary forms of management-system structure: one for a calendar-scheduled and the other for a free-running or individually student-paced course. There are certain management requirements common to both of these structures; these common features will be discussed first. The course has already been arranged into units or chapters. Also, within those major clusters you have a set of information panels that describe the objectives. Assemble all materials for the first chapter. This includes all test materials, study materials, and other instructional components. Review these materials briefly to reestablish the overall picture in your mind.

2. A major posttest previously prepared in Phase I must be given at the end of this cluster. Also prepared during Phase I are the "highly probable" incorrect answers for use in discrimination training, and a large bank of additional test items--problems, questions, and tasks--including the sample test items written to clarify the objectives. Review the chapter posttest and decide whether you still feel that the posttest is adequate. Does the test still seem to cover everything that needs to be covered, is it written in appropriate form, and have all irrelevant items been removed? Make any necessary revisions, additions, or deletions. Do this for chapter one only at this point.

3. Now review the sample test items alongside the posttest. Is the set of sample items complete enough (in conjunction with the objectives) to provide adequate information for the students so that the posttest will have no surprises or require any unanticipated competencies? If the posttest contains any surprises at all then the sample items and/or the information panels are inadequate. Revise and expand if necessary.

4. Prior to taking the posttest the student should have had the opportunity to evaluate his own progress. Even though we have given him a great deal of information regarding the performance capabilities and competencies that will be expected of him, his first opportunity to determine just how well he is progressing, and whether or not he has achieved a given objective, should *not* be kept from him until the posttest. A self-evaluation test should be prepared; draw on the many test items that you have already prepared, and design other questions, problems and task requirements that appear to test the same knowledge and skills. Direct questions requiring constructed or essay answers are generally much easier to prepare, often more appropriate, and provide immediate informtion regarding progress and problems for the student. The self-evaluation test can include items

that test clusters of objectives or single objectives. Generally, a combination is desirable. Be sure that each objective making up a trouble topic is tested by a separate item in the self-evaluation test. Prepare such a test now. Then repeat steps 2, 3, and 4 for all other chapters.

5. Now prepare a set of directions for the student. This will be added to the package of information already prepared for the student. Thus far the package contains the information panels that serve as objectives, the sample criterion test items, and the list of resources and materials keyed to the objectives. The directions should indicate locations and scheduling procedures for: individual use of materials, devices, group meeting, meetings with instructors, availability of tutors for consultation, and so on. Although much of the general information that the students will need can be anticipated, some unanticipated problems will develop. In a later section of these guidelines the method of providing for and recording such events will be discussed. At this point add the following items to the list:

    a. Location and method of obtaining study materials (if this has not already been done).

    b. The schedule (whether group or individualized) for all group sessions or the latest possible completion dates for individual chapters.

    c. Location of the recommended audiovisual materials and equipment. Include a schedule of availability.

    d. Method of scheduling meeting with the instructors for assistance, remediation, testing, and review.

    e. A list of directions should be included telling the student about each of the required activities, his options and how to choose among options. In general, attempt to provide all the guidance the student might need.

    f. Following each information panel should be the sample criterion test questions associated with the objectives implicit in the panel.

    g. At the end of the packet of information that accompanies each information panel, include directions for answering the sample criterion questions. Direct the student to complete the self-evaluation test. Self-scoring, "responsive" answer sheets, or responsive testing devices should be used if possible in order to provide immediate confirmation or correction of each answer. If this cannot be done, the student should be told where to go to obtain a scoring key so that he can correct his own test.

h. The response mechanism should contain a detailed discussion of the *correct* answer. Discussions of highly probable incorrect answers may also be included. In addition, the objectives and the related information panel should be identified, and remedial materials assigned. It will be necessary to remind the students frequently the self-evaluation test is a critical course component planned to help eliminate deficiencies prior to the posttest. There must be a "payoff" for them if they are to continue to play the game and follow the rules. If the self-evaluation test is made simple compared to the posttest, much of the effort expended preparing for the self-test and studying the remedial materials will have gone to waste. The student should be able to predict his own ability to perform well on the posttest, first on the basis of the objectives and sample items, and second on the basis of having taken the self-test and having completed any necessary remedial materials. If the student is not able to predict with reasonable confidence just how well he is going to do on the posttest, he will quickly conclude that the materials and course structure are of little assistance to him. This confidence is necessary if the student is to carry out his assigned role in a system that depends on his active participation as specified.

i. Additional materials are needed for trouble topics. A larger set of options should be offered; more explanatory text materials (such as programmed texts) and items for the self-test that evaluate smaller segments of each objective should be recommended. If time permits, prepare an additional set of practice exercises, practice problems and additional explanatory material with detailed elaboration.

j. Specify in the directions that all practice materials are to be submitted as completed. Emphasize that the materials handed in will provide useful information for further improvement of the course. This is true only if the materials are submitted without changing them in the attempt to present a better-than-actual picture of student progress. Students are often inclined, however, to view this statement of purpose with suspicion. In their experience, submission of written material has always been used by their instructors to flag their deficiencies and modify their grades.

As a natural outcome, they endeavor to submit flawless work which too often is a consensus of the thinking of other people. For these students a large part of the diagnostic function will fall to the posttest, hence it must accurately identify deficiencies. Students who do not carry out the assigned activities, including the diagnostic materials and self-tests, will usually arrive at the posttest having failed to achieve all of the objectives tested by it. The test must accurately evaluate the students on each objective and identify deficiencies. Trick questions, questions that are ambiguous, questions that require more than the students were led to expect, or questions that are far too simple for the specified level of complexity of the objective, all will undermine the system and cast doubt on the relevance of its components. Unless the students learn to trust the system, self-tests, student self-evaluation, and other management requirements that depend on complete student cooperation will suffer. This is bound to be reflected in total or partial failure of the management system.

All submitted material that is identified as progress assessment information must be evaluated *immediately* so that instant feedback is given to the students. Here again, if the students see that the management system is not responsive, it will affect their view of the system; more important, however, is the direct value of immediate feedback and the critical assistance that it provides. Several options are available. These make it possible to perform either the data collection function, the feedback-to-students function, or in some cases both:

(1) All practice materials may be collected for course evaluation purposes by having students turn the material in without entering their names on the materials. This approach attempts to minimize distrust and cheating in the preparation of materials to be submitted.

(2) Practice materials and self-tests may be brought to the instructor for review and discussion purposes but be retained by the student. The necessary progress evaluation feedback can be provided, remedial tutorial assistance offered, or remedial materials assigned or suggested. Course evaluation data obtained by this method, unfortunately, is not usually as reliable nor objective as it might be.

(3) Students may be required to turn in problem summary sheets which identify the problems they missed, describing their difficulties, and stating what remedial action was followed. They may also be asked to rate the difficulty of the test items or practice problems, and rate the value of the instructional materials.

6. Review the directions and attempt to judge their adequacy and completeness. Revise and expand if it appears necessary.

7. The guidance materials for the student will have to be assembled, duplicated, and distributed. Devise a standard format so that the student will develop a pattern for studying the information panel objectives, the sample criterion test items, and the available options. Prepare a format for a standard table of contents with the same items in the same sequence for each set of materials. Do not yet duplicate materials on a large scale.

8. Review the structure of the course. Each package of materials leading to a posttest should be appropriate for one week of work on whatever hours-per-week involvement the institution judges to be acceptable. For example, if a week's work is generally considered to consist of 150 minutes of group instruction plus 300 minutes of independent study and 120 minutes for special projects and assignments, the total is 570 minutes. Deduct from this figure the time required for group-scheduled instruction (lectures, films, etc.). Does it appear reasonable to expect every student to complete the work contained in each package in the amount of time left? At this point in the course development, it should appear reasonable to expect all students to complete the work in *less* than that amount of time because additional time will be needed for testing and remedial assignments. It is possible that certain courses as they now exist in terms of content and general goals, are very poorly assembled in relation to the standard calendar blocks of time available. A typical one-semester course is normally scheduled for approximately 16 weeks; not all "bodies of knowledge" neatly fit this time frame. A student might well be able to achieve all objectives specified as the minimum level in four hours of study per week for only nine weeks. In that case there is no problem. But difficulty will be experienced with the course that requires ten hours of study per week for 22 weeks for students to achieve the minimum level of attainment. Typically, instructors adjust their courses to the calendar. They either cram it all into the available number of weeks, or they cut off the end of the course, omitting certain chapters or topics altogether. When the minimum level of objectives for an entire course is specified, neither of these options is available. Students cannot take all the time that is necessary and let their other courses suffer--this is

poor politics as well as poor judgment. A curriculum modification might well be necessary, rebuilding courses to fit student learning requirements rather than calendar requirements. This is not always possible even though the specifications of the desired learning outcomes and the related student data might indicate that more time is required than the calendar allows. Some of the compromises--many of them unfortunate but required by practical, real-world considerations--that might be necessary in the name of accountability will be considered later.

At this point, it will be necessary to review the packages and make some preliminary judgments regarding time commitments for a group-scheduled course if this is applicable.

Since this is the experimental version, all estimates of time requirements, difficulty and probable remedial requirements for all students to achieve at least the minimum level of competence as indicated by the criterion test must be viewed as first approximations. As tryout data are collected, an empirical basis will become available for revising and restructuring the course, expanding or contracting the estimated length of the various components. So, at this stage of development, experience and judgment are the tools that must provide the estimates that are required. Review all materials, drawing on the experience and judgment of instructors who have previously taught the material to comparable target student population.

9. Ideally, you should now have test students available to provide some preliminary evaluations of the usability and adequacy of the materials you have prepared. Regardless of the skills brought to bear on this first version, there will certainly be problems, inadequacies, and gaps in the guidance you have attempted to provide. The target student is in the best position to recognize and identify these deficiencies for you. At this point we are not concerned with the diagnostic or directional adequacy of the sample criterion questions, the self-test problems, or the posttests, nor are we interested in determining the effectiveness of the various instructional components. This analysis will require a more extensive and complex collection of data. Here we are concerned only with the management aspects of the packages that you have prepared: are the directions clear and unambiguous from the student's point of view? Is the student able to follow the directions, locate the designated materials, comprehend the array of information that you have provided, and so on? In other words, as a "road map" for the course, are your sets of instructions and directions adequate? It is recommended that you select approximately ten students, some of whom have been rated as above average in intellegence and articulateness by instructors of other courses. Meet with them as a group, if possible. Explain the course to them; tell them its general contents, what you are attempting to do, and explain the various management and direction functions that your materials must perform.

Ask them to contribute one to two hours of their time to help "trouble shoot" the package. Ask them to put themselves in the place of students who are about to begin the course, and to examine all of the materials in the first package (or chapter). Encourage them to be as critical and as detailed in their examination as possible. Have them write any questions that occur to them--questions about the meaning or intent of any of the directions or information, identifying steps that are not clear. Students who are competent and self-confident tend to enjoy participating in activities of this sort. They can provide suggestions and identify deficiencies that will assist you in making significant improvements in the materials. We do not recommend having the group discuss the materials and interact with each other or with you. It is useful, however, after collecting the information they have produced, to meet with those who seem to have made the most useful comments for further discussion. It is recommended that only the first package be reviewed by students in this manner since all later packages assume that the objectives of the first package have already been achieved.

10. Review the information obtained. Revise the materials if comments and criticisms appear valid and if the suggested changes appear worthwhile.

11. Is it possible to obtain a test group of students to take your course? It can be offered to a few selected students who plan to take the course at some time in the immediate future. They can be assigned to take the test version while the existing conventional course is administered to all other students exactly as it would have been if this project had not been undertaken. Depending upon the availability of students, a group of as few as six students or as many as twenty could be assigned to the experimental version of the course. It is far more convenient to do this than to assign large numbers of students to this formative version as a substitute for the existing course. The experimental course is not yet ready for large-scale implementation. It should be offered for credit, however, whether it is run during the school year, paralleling the existing course, or run during a period when the existing course is not taught.

    The less attractive alternative is large-group course implementation replacing the existing course or offering it as a new course. Because accountability requires that student deficiencies and course shortcomings be identified immediately and as accurately as possible, course management problems may be severe. In addition, the data must be collected in a form that will permit appropriate revision requirements to be identified. This test version of the course is immature; it is easier to test and manage it when fewer than twenty students are involved. If only one or two instructors are available the test-student group should probably be limited to 10 or 12. If they constitute the total staff, however, without support for data collection, analysis, test solving and other activities, no more than four students should be involved. Although rules of thumb are arbitrary, and project staffing requirements can vary as a function of a number of variables, the following project staff/student ratios are suggested as minimal (not including clerical help):

| *Students* | *Instructors* | *Support Staff* |
|---|---|---|
| 5 | 1 | 1 |
| 10 | 2 | 2 |
| 20 | 4 | 3 |

Make the final decisions regarding the number of test students, the schedule, and the staffing assignments at this time.

12. Unfortunately, it is not always possible to limit the number of students assigned to the first test run of the course. It is also possible that when that is the case, the project staff (instructors and support staff) available will also be limited and less than adequate for the task of making this version of the course work. It will be noted from the table in item 11 that the recommended student-to-instructor ratio is 5:1, part-time or full time. This ratio is also recommended for larger groups of students. Thus, for a test group of 60 students, 12 instructors are needed. If this is not possible, diagnostic test evaluation, individual consultation, and tutorial instruction will not be possible on as large a scale as would be desirable. The course will not be as effective as it might be with a smaller student/instructor ratio, but the necessary revision data can still be collected. The posttests should be scored immediately and remedial assignments should be made, despite the fact that individual tutorial-remedial instruction will not be possible. If a large group of students is to be involved in this first course tryout, you will have to develop a method of having tests and other hand-in assignments scored. Remedial topics will have to be identified for each student (identified in terms of the objectives and/or sample criterion test items) and returned to them within 24 hours. Instructors should be available for consultation immediately after the remedial topics have been identified. Each instructor should also be given the diagnostic information for each student for whom he is responsible. He should then pass the information along to each of his charges. This does not necessarily mean that he must tutor each student in the applicable problem area, but he ascertains that each one does relevant remedial work, rather than carrying the deficiency on to the next assignment. Here again, the practical limitations might make this impossible. This is an unfortunate reality that sometimes cannot be avoided, so that the course may not be as accountable as it should be, even at this stage. Whether large-group or small-group testing is to be involved, develop the necessary test scoring and feedback system now.

13. The Boy Scouts of America have for years evaluated the progress and competence of scouts being considered for advancement and merit badges by means of a very direct and relatively simple, but powerful methodology. Certain requirements must be met, activities carried out, and projects completed to the satisfaction of the scout's immediate adult supervisor, the scoutmaster. The scout then appears before a Board of Review made up of adults involved in scouting activities and familiar with the requirements of each progress component. The Board uses guidelines in printed form for evaluating each scout to appear before it. The scout faces an oral and performance examination wherein he might be called upon to discuss or demonstrate anything relevant to the requirements. Since the objectives are perfectly clear to the scout, his scoutmaster, and to the members of the Board of Review, rarely does a scout fail to demonstate the required competence when he appears for examination. A similar procedure can be used to good advantage as a method of identifying student and course deficiencies. Too often, educational evaluation is limited to paper and pencil forms of tests. This might be necessary for large-scale, standardized, normative testing, but no such limitation need be imposed on course development and formative evaluation. We can frequently learn more about a student's achievement and the effectiveness of the instruction he has received by discussion. We can ask him to explain, describe, demonstrate, carry out tasks, or whatever might indicate where his competencies and deficiencies lie. This can be done informally or systematically. Unless we are directly concerned with writing skills and communication skills, it should be done orally rather than in writing. To be sure that no details are lost, the discussion may be tape recorded. It should be remembered that the purpose here is the identification of deficiencies that can be traced to problems in the instructional directions, guidance materials, or instructional resource materials. The posttest may be used for these oral examinations. You should explain this procedure, indicating that students will be selected for the oral examination version of the posttest in such a way that each one will be given the oral examination every few weeks. It will be necessary to stress the purpose of the examination. Students should not be told in advance who is to be given the oral examination. The student who is to take it should discover that only when he arrives to take the posttest. Score each item on a minimum acceptable level as closely related as possible to the criterion that you will use for scoring the other posttests. You may ask questions about various sub-objectives or components of objectives, and any other questions that will help you make decisions about course revisions. But it should be made clear to all concerned that the test scoring is handled exactly as it would be if the student were taking the regular posttest.

At this point, bearing in mind all the possible forthcoming problems unique to your situation, work out the details of the steps that you will have to follow to implement this part of the course management procedures.

14. Now there are a number of housekeeping procedures that must be established. Some of these will have to be prepared as ground rules for the students and prepared as handouts for them. Local requirements and constraints will determine for you just how each of these steps must be handled. Prepare a check list that includes every detail of concern to you and the students. Determine, *in advance* of the time at which an action must be taken, exactly what problems might arise, and make the necessary preparations.

    a. Generally each student will have to have his own copy of the primary textbook, and arrangements for these materials will follow usual procurement and distribution lines. Identify all other materials that each student is to have in his possession. These will include the packages of directions, objectives, workbooks, programmed texts, reference materials, tests and practice exercises.

    b. Identify the study materials that the student will have to obtain from some person or facility for use as needed. These might include other textbooks, reference works, audiovisual materials and devices, supplies and equipment. You should consider concentrating all materials in a single study center. This would involve assembling materials from the library, the audiovisual center, and other sources. If you choose to go in this direction, you should arrange for a resource librarian to control the movement of these items.

    c. Specify the conditions and procedures to be followed for distributing the student materials--when and where they are to be obtained by the students, what materials have to be signed for and returned, and which materials (practice exercises and practice tests, for example) are to be submitted. Specify the place, time, and recipient of submitted materials.

    d. Establish detailed procedures for: the administration of the posttests, scoring them, preparing the diagnostic summaries, preparing remedial topic lists, and the method for distributing them to the students. In addition, set up standards that each student must meet before being allowed to take the posttest. These might include completion and submission of practice exercises and self-evaluation tests. This is primarily a management and control procedure. If students are permitted to take the posttest without demonstrating that they have completed the self-evaluation test and have taken remedial action, some students will take the posttest without preparation just to obtain information about the questions. The self-test has the sole function of evaluation and diagnosis for the student's benefit. It is imperative that the results of the test are not used to grade the student or in any manner punish him for his mistakes. If the students are to use the self-test as their admission ticket to the posttest, it is suggested that the self-tests *not* be collected unless the data is truly needed for revision purposes. Each student may be required to meet with his sponsor to discuss the self-evaluation test, either to help him select the remedial procedures and materials that he will follow, or, after the fact, to discuss the remedial steps he has followed. The remedial action taken by a student following a self-test or posttest is an item of information that should be collected from him; we will discuss this point shortly. Develop the list of procedures to be used for the administration and scoring of posttests, and for disseminating the diagnostic analyses.

e. A form should be prepared so that students can submit written evaluations of the clarity, general quality, and effectiveness of the materials. Active management is required to see to it that forms given to students to fill out are actually completed and turned in. It is not enough to distribute forms, ask the students to cooperate, and assume that nothing more need be done. A specified time--either in terms of an assigned date, or event such as "just prior to taking the posttest" should be scheduled for submitting the forms. The forms should not simply be filed away, for several reasons: while the experiences of the students are still fresh, additional follow-up might yield even more detailed and valuable information; the students will not take the forms seriously unless they can see the course managers and instructors take them seriously, and examine the information as it is received. Useful information submitted by a student should be identified and the student should be told that his assistance is appreciated and that the information was well prepared. Students who are careless or who do not prepare the forms as requested should be contacted and given assistance if necessary.

There are several very useful kinds of information that should be sought. The objectives, information panel content, sample items, and directions given the students are supposed to be helpful and provide useful guidance and direction. Do the students find every item to be unambiguous, germane, accurate, and useful in a practical way? Accompanying the posttest, items similar to the following might be provided:

(1) How well did the information panel serve as a guide to the requirements of this unit (chapter, etc.)? (Use the letter A to indicate "exceptionally well", the letter E to indicate "very poorly", and letters B, C, and D to indicate "very well," "moderately well," and "fairly well," respectively.) ____________

(2) How well did the sample test items clarify what was expected of you?______________

(3) Were any of the posttest items more difficult or more complex than you were led to expect? If so, identify them here by number:_________

(4) Now that you have completed the posttest, can you think of any instructional materials or activities that were ambiguous, irrelevant or not very helpful. If so, describe or otherwise identify them:

________________________________________________

________________________________________________

(5) On this posttest, which two items were the most difficult? _______ _______ the least difficult? _______ _______

(6) Do you think that any test items were ambiguous, unclear, or unfair? If so, identify them here: ____________________________

(7) Think about the instructional materials and activities that were selected to prepare you for this posttest. What others would you suggest to provide additional assistance for the next group of students? __________________________________

________________________________________________

(8) What did you like most about this unit (chapter, etc.)? ________________________________________

(9) What did you like least? ______________________

If feasible, have students record times spent studying and resources used.

When we discuss the first revision based on the first trial run-through, we will examine some of the other assessment possibilities. After this first rough version is tested and revised, we will want to become much more precise and "molecular" in the search for pertinent data and information for further revision purposes.

We shall want to document everything we can rather than trust our memories or impressions. As instructors are consulted by students, the instructors should prepare brief written descriptions of the topics about which questions were asked and assistance sought. It is sometimes difficult to convince instructors that this is worth doing. It is the responsibility of the management staff to insist that instructors do in fact prepare such records. This requirement is a continuing one; if the management staff eventually stops stressing the importance of the records or provides no feedback to the instructors, then the latter will consider the records unimportant busy-work and will stop preparing them. Remember that the kinds of details required for the effective implementation of this model are far more varied and specific than those needed for non-iterative procedures. Instructors may view with alarm the data collection requirements of this approach, but without these data the model will flounder, and accountability will not be achieved.

The forms to be used by the instructors to record the nature of their contacts with students should include *at least* the following: objective(s) discussed; sample criterion items identified as ambiguous; sample items to which students could attribute little or no value; nature of the problem in as much diagnostic detail as the instructor can provide; remedial action taken or remedial activities suggested; and any other comments that might help pinpoint the nature of the difficulty.

At this point, prepare the forms to be used by the students and the instructors to record their observations, evaluations, and experiences. As you prepare these forms, keep in mind the purpose for which information is being sought: the first version of the course is to be revised and improved. We must learn what needs improvement, and what portions seem inadequate. It does little good, for example, to ask the question, "Do you like this course?" Neither a "yes" or a "no" helps make revision decisions. The question should ask the student to indicate *what he likes most or least* about the course.

f. After preparing the forms, sequence the procedures you will follow in presenting information to the students about the purpose of the forms and the method of use. Be sure to indicate in your plan that only enough forms are to be duplicated for the first two units of the course. After the first posttest and after the first set of these forms have been completed by the students and collected, they should be discussed with at least some of the students to determine whether the forms can be revised and improved to produce more pertinent and informative data. There is no need to wait until the entire course has been completed to make revisions that might increase the effectiveness of the information-gathering process.

g. One of the fundamental facets of accountability is that the empirically iterative process must result in the development of a highly effective course. All necessary provisions must be made to "pick up the pieces," to identify each student's deficiencies (resulting from failures to achieve objectives), and then to repair that gap in his achievement. One of the greatest shortcomings of most conventional instruction is that failures and deficiencies are allowed to accumulate. Students fall behind, failing to execute certain objectives, and cannot take the next step because they have not developed the prerequisite skills for what follows. This is most critical in cumulative courses in which each new set of objectives draws upon the competencies already developed. Accountability requires the identification of failures, regardless of their cause, and systematic remedial efforts in time to prevent the "cumulative failure" syndrome from developing. The implications are effective as well as cognitive. Dr. William Glasser, founder of the Reality Therapy Institute, and developer of the "schools without failure" concept, emphasizes several related ideas. Students of all ages in our society are seeking *identity*--according to Glasser, they are more identity-oriented than goal-oriented. And he says, as students experience failure particularly if they have not previously learned to view themselves as successful and competent individuals, they will learn to view themselves as failures and to *expect* to fail. This expectation then becomes a "self-fulfilling prophecy." There is no justification for not following up student failure with appropriate remedial action. If a student does not achieve an objective, what can possibly justify permitting him to carry that deficiency forward into other situations in his future? The importance of *diagnosis* and *remedial instruction*, particularly during the early stages of empirical course development, cannot be overstated.

We have used the word "sponsor" to refer to the instructor's assignment in relation to each of the students identified as "his." The instructor's flexibility--his ability to adapt to the needs of each student--is perhaps his greatest capability. Unlike a textbook, film, tape, or program, he can be totally responsive to the student. Not every instructor will succeed in developing these skills. At this stage, however, each will have to attempt to be a diagnostician and remedial tutor. The sponsor is directly accountable for each of his students. It is he who has the direct responsibility for maintaining frequent contact with his students, for reviewing posttest diagnostic information, helping students select remedial materials (or providing that remedial instruction), and breaking the cumulative deficiency chain.

Prepare a set of procedural guidelines for the sponsor to follow. It is suggested that the student be required to meet with his sponsor at least twice during each unit--once following the self-test to discuss problems identified by the student, again after completing the remedial activities performed to correct deficiencies identified by the self-test. This second meeting will precede the posttest and will allow the instructor to determine just how effectively the deficiencies have been remedied. Of course, the student will also be permitted to consult with his sponsor at any time for additional assistance, enrichment, or any other need. Incidentally, the schedules of the instructors should be arranged to make it as easy as possible for the student to meet with his sponsor without having to wait several days.

h. The forms described in step (e) should facilitate the recording of information that will help make revision decisions. These will identify topics and objectives, problems, and remedial action taken. Another form, labeled "Recommended Course Revisions," should also be designed. Each instructor should prepare one weekly or more often if necessary. An instructor who has seriously attempted to apply the accountability concept to diagnose and tutor, will be dealing directly with objectives and with student's ability to perform the actions required by the objectives. The instructor will find that some approaches work more effectively than others. He will often be able to identify with considerable precision and detail, information, questions, problems, exercises, tutorial sequences, examples, and analogies that help the students achieve the objectives. The remedial and tutorial sessions with the students can be a significant source of valuable instructional content, methodology, and procedures. This experience should not be bypassed. Recommendations from instructors after these sessions can do much to suggest fruitful modifications for the next version of the course. Weekly meetings should be held with the instructors to emphasize the importance of collecting such information, to provide active management which insures that the forms are completed, and to encourage active participation and interaction by the instructors. They should be encouraged to fill out the forms following each remedial meeting and to expand on the suggestions already entered on the forms during weekly group meetings. Plan the procedures for scheduling and conducting the group meetings with the instructors.

i. Consider another possible source of remedial instruction or small-step guidance for the slower, less capable student. There are hundreds of published programmed textbooks covering most academic subjects and many vocational topics. Your department will generally have some information available from the publishers, describing what is available. Obtain copies of programs that appear to match your objectives. Request descriptions of the objectives and field test data from the publisher, the former to see what the program attempts to teach and the latter to find out how well the program teaches those objectives. If the publisher cannot provide both objectives and test data, discard the program. You are using an empirical, iterative approach--an approach that entered education primarily by way of programmed instruction. The validity of any program that was not developed in the same fashion is dubious and not worth considering. Where suitable programs have been found, identify them as enrichment or remedial sources and establish a catalog for student use.

15. Since the development staff might not include the instructors who are to be the sponsors and managers, a training and indoctrination session or workshop is necessary. This workshop must cover the following topics: (a) Course structure should be described and explained. The instructors should be walked through the detailed procedures that they must carry out, and the rationale of the approach must be discussed in detail. (b) A description of the accountability concept must be given. This concept requires that *all* students attain at least the minimum objectives established for the course. The first version of the course is not expected to achieve this goal in an accountability view. This is to be contrasted with the more conventional view which simply fails some of the students while calling the course a success! (c) The empirical approach must be stressed. A detailed analysis of results of one tryout will make the next revision in the series more successful and closer to the target level of success. Place emphasis on finding out what the weaknesses and deficiencies are, rather than concentrating solely on the strengths and successful components of instruction. Both are important of course, but if a very bright student learns in spite of deficiencies in our course, that tells us very little. Any time a student has difficulty or needs assistance, that identifies an objective and related instructional materials and activities that may need to be revised and improved. By indicating how the detailed data will be used, the instructors will view the data-collection requirements as relevant and worthwhile, rather than as busy-work.

16. Two characteristics are required of diagnostic and remedial materials; they can be scored by the students themselves, and they provide immediate remedial feedback.

The possibilities for self-testing include: a responsive answer sheet of some sort (such as wet-to-reveal sheets), a self-scoring testing device, an answer key for the student, or possibly a computer. The students' answers, in appropriate form, can be fed to a computer for scoring and evaluation, and the computer can provide a diagnostic print-out for the student. If resources are available, the student could take his self-tests and posttests directly on a computer terminal, and receive immediate feedback scoring and discussion, possibly remedial tutorial via computer-assisted instruction (C.A.I.). Computer management of a course, even if restricted to simple record-keeping, keeping track of individual progress and schedules, and diagnostic test evaluation, *is also an empirical developmental project*, requiring design, testing, and revision. Before committing yourself, be sure that all of the necessary expertise is available and all the resources, and all of the time required to develop a working system. Be sure that alternative procedures are established to accomplish all of the functions described here; with time, many of them can be taken over by a computer.

The self-tests should have some scoring procedure that will inform the student immediately whether each answer or action taken was appropriate or not. Ideally this should be accomplished as each response is made, or at least no later than immediately following completion of the test. An absolute minimum form of remedial is an indication that the objective was missed, and that additional study is required prior to taking the posttest. Even though the student is referred back to relevant resource material, it is desirable to include a brief discussion of the test item or problem explaining the correct answer and the steps in attaining it. Specify the exact location of the related information panel, and the most appropriate review and remedial study materials. If you have chosen to make use of programmed texts for remedial purposes, the relevant materials should be identified for each test item. Prepare the same information for practice problems and posttests.

17. Rather than attempt to develop a completely multiple-choice test, it is suggested that you develop test items in the most directly relevant form. Multiple-choice items indicate whether or not the student can discriminate between correct and incorrect alternatives. Other objectives require constructed responses and actions to be taken. Criterion tests and posttests are more difficult to administer if this suggestion is followed, but when small groups are involved the task is not unmanageable, and the information value of the data will be worth the additional trouble.

In preparing constructed response items, it is necessary to make the evaluation of responses as objective as possible. For each item a decision must be made specifying whether that item is to be evaluated on an all-or-none basis, or whether critical components are to be evaluated indiviually. We have to serve two requirements here: evaluating the student for administrative purposes, possibly in terms of letter grades or a "pass-fail" decision; and also, for the empirical model, identifying deficiencies and revision requirements.

Scoring keys should specify the minimum components that must be present for a response to be judged acceptable or correct. This criterion must accurately reflect the requirements of the objective and must be rigorously applied in evaluating student responses. When scoring the test items, any component required by that criterion and missing in a response should be identified in the analysis of test results. Each missing component is an indicator that may be useful in making the revision decisions.

Tests should be evaluated as soon as possible after their completion. For purposes of making revision decisions, you should consider calling students back to obtain additional information if necessary. For example, if a student does not successfully complete the minimum requirements of a test item, and it appears that the item may have been at fault, an interview may determine whether or not the required level of competence was present.

18. The first test version is now ready for implementation, following the preparatory steps described up to this point. The next section of Phase III, Part C deals with the analysis of results, revision procedures, and successive expansions of the course management system. Administer the course and collect the data.

Section Two: Analysis of Results and Revision Decisions

1. Assemble all sets of information: posttests, final criterion tests, student and instructor ratings, instructor tutorial reports, etc. We will start with the final criterion test. Many conventional statistics can be obtained for these test items using readily available computer programs. Arrange to have a conventional item analysis run on the criterion test items indicating percentage correct, and in the case of multiple-choice items, the percentage of students selecting each incorrect choice. The analysis should also give the percentage of students in the upper half of the group who answered each item correctly, and the "validity" correlation. These familiar analyses will provide a first view of the data and let us identify the more serious problems.

2. Prepare a student test item table with columns representing students and rows representing test items. We are interested

here in individual responses to each criterion test item. All test items except multiple-choice items should appear in this table with an X indicating a correct answer, and a dash representing an incorrect answer. For multiple-choice test items, indicate the letter or number of the choice selected by each student. The table might look like this:

| | STUDENT | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST ITEM | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | % |
| 1 | X | X | X | X | X | X | - | X | - | X | 80 |
| 2 | - | X | - | - | X | X | X | X | - | - | 50 |
| 3 | X | X | X | X | X | X | X | - | - | X | 80 |
| 4 | - | - | - | - | - | X | - | - | X | X | 30 |
| 5 | a | a | c | a | b | a | a | d | d | a | 60 |
| n | X | X | - | X | X | X | - | X | - | X | 70 |
| Score | 4 | 5 | 2 | 4 | 4 | 6 | 3 | 3 | 1 | 5 | |

3. We must examine the validity of the test items. It is possible that a missed criterion test item indicates an objective that a student did not achieve. It is possible that a test item and its scoring key are not relevant to the objective, or that the objective is tested at a higher level of complexity than is appropriate, or simply that a test item is ambiguous. Examine the table and in the left-hand margin identify the objective covered by each test item indicating also any objectives tested as part of sub-components of an item. (Any convenient labeling system will do.)

   You need, in addition to the table, a master chart listing all objectives. The master chart should also refer to the sample test items provided for the students, and the final criterion test items indicating the minimum acceptable answers. The chart is the master reference instrument against which all obtained data must be evaluated; presumably the chart identifies the desired outcomes, the specifications of the terminal competence required of the students.

4. When the item analysis data are available, each test item should be studied to determine what the data indicate. At this stage of development, the course cannot be expected to work very well. Consider, for example the hypothetical data contained in the table above, based on ten test students and six of the objectives.

The item analysis data summarizes what the table shows in detail. It also indicates the correlation between each item and the total test score, which at this stage of development should be high and positive. A negative correlation immediately identifies a questionable item, as does a ratio indicating that more students in the lower half of the group were correct on an item than were students in the upper half of the group.

The item analysis for the multiple-choice items will give the percentage of students selecting each of the choices. Different patterns suggest different kinds of problems: if there are many incorrect choices of one alternative, apparently the students cannot discriminate between that choice and the correct one. When numerous wrong choices are scattered over all alternatives the problem is apparently more serious, since the correct alternative does not stand out from any of the distractors. The deficiency is even greater when the number of correct answers is relatively small.

With these considerations in mind, and using the table and item analysis data, perform the following tasks:

a. Identify and list all items answered correctly by more than 70% of the students (that percentage is artitrary and could be set either higher or lower). Ask the instructors to examine the questions and related answers, compare the questions and answers to the specifications of the master chart, and indicate whether they think that the item is appropriate in degree of difficulty. An item answered correctly should indicate an objective that was achieved. We must be as suspicious of items that most students answer correctly as we are of items that many students miss.

b. Identify and list all items that were answered correctly by less than 30% of the students. Ask the instructor to examine those items and identify test items that they feel are ambiguous, too complex, or inappropriate for any other reason.

c. Review the decisions of the group of instructors on tasks (a) and (b) above. If possible, ask another group of subject matter experts to make some judgments. Discuss both sets of judgments and arrive at a concensus on each item.

d. All items identified as requiring revision should now be revised. This should be done by those individuals who have demonstrated or expressed interest and some competence in developing test items.

e. As each item is revised, review the related information panels, or whatever other form the objectives take that are given to the students. Review also the sample criterion items and the self-tests and posttest items associated with objectives for revised items. Change the other materials if necessary to conform to the structure of the new criterion test items.

5. Prepare a description of the results for all test items summarizing the data from the table and the item analysis. A description based on the sample table described earlier might look like this:

[*Item 1. Eight students correct. One of the two students who missed it was in serious trouble, missing five of the first six times. "Validity coefficient" is + .42 (of limited value because of small n and large percentage of correct answers). All students in upper half of group correct, three of five in lower half correct.*

*Item 2. Five students correct. r = + .24. Three students in upper half of group correct, two in lower half correct.*]

In most cases, the summary of data for an item will not have to describe each additional kind of information to be examined, because all data will generally have to be reviewed. Special emphasis on one kind of information might be indicated, or initial impressions might be described. You can then describe whatever other impressions you have. For some items a tentative revision recommendation can be made.

6. The next step consists of an analysis of all test items not previously reviewed in steps 4(b) and 4(a). Those were the most likely prospects for major revision, so we have had that work completed first. Now it is time to review the remaining items on the final criterion test. Provide your team of subject matter experts, who are to perform this function, with a copy of the data summary prepared in the preceding step. Give them the following directions: (a) Considering the data for each item, examine the item in relation to the objective that it is designed to test. Note any ambiguities or possible misdirection in the item. (b) Review the student comment sheets and determine whether or not students said anything about the item that will help your analysis. (c) Check instructor records to determine which students requested help and what assistance was given. Examine remedial records associated with this objective. If possible, this may include interviewing the students to determine what they had and had not learned about the objective. (d) If the item appears valid and is not too easy or too difficult, put a red check in the margin of the summary sheet beside that item. If you feel that the item should be revised, revise it. (e) Prepare a Revised Criterion Test Master Sheet. Retaining

the same numbering system (for convenience in further reworking and review) key each test item to this Master Sheet, either the original item if it was not revised, or the new revised item. Put a red check mark in the left margin beside the newly revised items.

We should not assume, unless there is other evidence to justify it, that a correct answer means the objective has been learned or that an incorrect answer means an objective was missed; the test items could be too easy, too difficult, etc. There will be a temptation to accept a correct answer as good news, but items responded to correctly must be examined as closely as those most students missed.

7. Prepare a summary sheet (similar to that described above) for the posttest data. List the posttest items in sequence, following the same numbering used on the posttest itself. In the left-hand margin write the number of the objective and the number of the final criterion test (if the numbers differ) to facilitate examination of all test items dealing with a single objective. Identify the percent of correct answers for each posttest item.

8. Ask the same group that reviewed and revised the final test items to review the posttest items and make necessary revisions. Follow steps 6(a) through 6(d) and prepare a Revised Posttest Item Master Sheet. Retaining the same numbering system, put each posttest item on this Master Sheet either the original item if it was not revised, or the new revised item. Again, put a red check mark in the left-hand margin, beside each newly revised item.

9. Put the two newly developed Master Sheets of posttest and criterion test items aside for the moment. These sets of test items should be significant improvements over the first version if the data were used effectively to direct attention to possible sources of deficiencies and inadequacies. By working on the test items first, you have effectively divided the course into two sets of objectives, those for which the final criterion test items were questionable and require revision, and those for which the criterion test questions were considered to be adequate measures. The red check marks on the item summary data sheets identify the former, and those without checks make up the latter. Now we must make some revision decisions, and we'll start with those objectives for which the test items were judged to be adequate.

    a. Start with the first criterion test item that did not have to be revised. Review the summary data and the table. If a relatively large percentage of students correctly responded, look at the column representing each student who missed the item. Were the errors made largely by students who had the lowest scores, or were they fairly well distributed over students with both high and low scores? If concentrated in the lower student group, this might be a trouble topic for the poorer students only. If more generally distributed, the instructional materials would appear to need strengthening for all students. Determine first which distribution of errors is present. Make a note of your finding.

b. Locate the related posttest item and sample item and self-test item. Do the sample item, self-test item, and posttest item appear to test the same objective at the same appropriate level of complexity? Make additional revisions of test items if necessary. As in (a) above, make a note of the type of distribution--poorer students or all students.

c. For each student who missed the criterion test item, determine whether he also answered the related posttest item incorrectly. Also determine how many students who missed the posttest item were correct on the final criterion test. Assuming that the test items were judged to be acceptable, there are four possible patterns, each of which suggests a different problem or possible corrective action: (1) both correct--no problem, (2) posttest incorrect, final correct--initial information and resources apparently not adequate, but the remedial or subsequent experience corrected the deficiency, (3) posttest correct, final incorrect--one prime possibility here is inadequate review and practice between the posttest and final, so that although the objective was achieved, retention was not adequate, (4) both incorrect--a major problem, since neither the original specifications and resources worked, nor did the remedial materials and resources correct the deficiency.

It is desirable to have a computer perform this categorization. If you do not have a computer available to determine all patterns for all students for all items, this task can be quite sizable.

Determine which was the most frequent pattern for each criterion test item. For example, item one might have four wrong-wrong patterns, three right-wrong patterns, three right-right patterns, and six wrong-right patterns. This item was answered correctly on the final examination by nine of the 16 test students, and incorrectly by seven. No one pattern predominates, so apparently the remedial was effective for some who missed the posttest item but not for others, and some learned but then forgot, and some did well on both the posttest and final. In this case, look back at the table and see if the right-right and wrong-right patterns tend to represent the students who had the lower overall scores. If so, make a note of this along with your notes resulting from step (a) above. If not, make a note that both the remedial and the initial resources have to be improved.

d. Consider first any items for which wrong-right was the pattern for 80% or more of the students.

The remedial was apparently adequate. Look at the records to see what kind of remedial instruction those students received. If it was largely text or programmed text, consider prescribing that for the primary resource materials. If the effective remedial was largely in tutorial form provided by instructors, consult with the instructors and consider having them prepare text materials, preferably programmed or at least in workbook exercise form, or having them prepare audio or audiovisual materials to provide the remedial instruction. Consider also attempting to make remediation unnecessary by putting the newly prepared materials into the basic set of instructional materials, possibly making it a required assignment or a student option.

What percentage of students missed the posttest item? If the data indicate that only 30% were correct on the posttest item, that is a very different situation than that indicated by, say, 80% correctly answering the posttest item. In the case of 30% correct, the remedial performed a major job, with the initial instructional materials and resources apparently accomplishing very little. In the case of the 80% correct, however, the initial instructional resources are apparently adequate for the vast majority of students, with the remedial resources providing the necessary supplementation. Let's set 70% as the cut-off point here between these two different cases. If the posttest average percentage correct was greater than 70%, we will for the time being make only minimum changes in the initial resources either adding additional materials of an easier form, or revising the information panel and additional clarification components. We must also look at the wrong answers to the posttest questions and consider adding short instructional text materials, attempting to provide additional clarification that might help prevent those same errors.

Look at the notes that you prepared for steps (a) and (b) above. Were most of the errors on the posttest item made by students in, say, the lowest 50% of the students according to their final exam scores? If so, apparently the instructional resources are adequate for the better students, but not for the slower students in the group. Consider specifying additional learning materials for students having difficulty. Identify them also as recommended study materials for students who miss the related item on the self-test.

If the posttest errors were distributed more generally over the full range of students, consider clarifying the information panels and related information, and adding some simplified instructional material.

e. Next, attend to the items for which 80% or more of the students had the right-wrong pattern. Here the initial resources were apparently adequate, and the remedial was not needed for most students. But between the posttest and final the students apparently forgot, and could not answer the final criterion question. You will have to provide some form of practice and review, for apparently this objective is not automatically reviewed by continuous use in later objectives. Add reviews to later practice exercises and problems. It is generally better to make the review interactive--in a test or exercise--than simply a narrative reminder of some sort. Design and develop the plan for all review materials.

f. The wrong-wrong objectives are a major problem, and so are items for which all four patterns were well-represented. For each item of that sort, a more detailed analysis is required. With all data at hand, a review must be made of the instructional resources provided. The information panels and supporting materials must be examined, and the several staff members working on this review will then have to recommend action to be taken. If it appears that the objectives and the sample items do not clearly define the competence that the student must acquire, those materials will have to be revised. All instructional presentations will have to be reviewed with an eye to improving their effectiveness by simplifying, clarifying, adding additional elaboration and more examples, and possibly by designing interactive presentation or materials.

The data identify trouble topics in addition to those we identified during the development of the course. For this revision we want to provide a major increment in the amount of direct assistance given. The data will indicate a narrow range from "slight deficiency" to "serious deficiency." We want to avoid making too great or extensive a revision when a slight change would have done the job. So at this level of development make changes as the data suggest, but even for the trouble topics use the more extensive interactive approaches only for the more severe problems.

For the other objectives attempt to improve the results by revising the student objectives, sample items, and the instructional materials and presentations, but at a minimum change level. The instructional resources must be treated with care, however, since it is not enough simply to throw some additional materials into the resource list. Eventually you could have the entire library on the list without having improved the results one iota! Review the student comments, determine whether any materials or presentations were criticized as being confusing, unclear, not helpful, etc. Among the minor revisions that might be considered for any of the patterns are: revising and attempting to clarify the information panels and related information; replacing too-complex instructional materials with simpler materials, adding programmed text and workbook exercises to the list of resources, and providing more practice problems. More extensive, major revisions include the development or selection of programmed text materials to provide the basic instruction; development of audiovisual materials for additional, supplementary (redundant) coverage; development of practice problems to accompany all study materials; development of programmed lesson plans for interactive group presentations if group paced (or for development of individualized audiovisual presentations for individually-paced courses), etc. The remedial materials can be revised along these same lines, depending upon the indicated need for improvement of these materials.

g. The objectives for which the test items had to be revised pose a different sort of problem. We have less information for these objectives than we did for the others. The first step is the detailed review of the responses. Multiple-choice items may not tell us very much, but those involving explanations, descriptions, definitions, and the completion of certain tasks can tell us a great deal. For example, a test item identified as too easy might still elicit enough information for us to be able to tell whether or not a student achieved the intended objective; that is a student might give more information than the easy item called for, actually demonstrating that the intended objective was achieved. But items that were identified as requiring revision sometimes give us much less information than that. The analysis of incorrect answers will sometimes suggest possible improvements, and areas requiring revision, but you might well discover that nothing in the entire set of data tells you enough to let you make a precise judgment about the revision requirements for certain objectives. We must use whatever other information we have. So review the student evaluation forms, the instructor record forms, and any other kinds of available information.

10. It is now time to look at the management system, and decide what revisions have to be made in management procedures. There were housekeeping functions to be performed, such as seeing to it that the necessary records were kept on each student, making the necessary materials available, scoring all tests and getting the diagnostic information back to the students and their sponsors, etc. Evaluate the methodology for test scoring, student evaluation by means other than through written tests, and suggesting the remedial routes and materials, by reviewing the records, comments, critical incidents, and any other sources of information.

The purpose of the management system is to provide the necessary responsiveness to student progress to make accountability work. Any report, comment, critical incident, or other indication of a course deficiency may signal a fault in the management system. Each failure that is identified calls for some modification in the course materials, methods, management, or all three. Identify the problem areas, and make those revisions that appear most likely to correct the problem.

Here again, you can see the potential of a computer for course management. Laborious, time-consuming requirements that are tied to a need for immediate analyses of results or compilations of data pose an almost insurmountable problem unless the speed and capability of the computer are available. Many of the critical incidents that have been identified describe time required to evaluate tests and return the data to the sponsors and students. The course development staff, including the instructors, probably had many problems that they had to solve and correct on the spot. Ideally, they all should have kept detailed records of such events so that those problems will not occur after revision. This is part of the empirical approach--collecting as much data as possible--so that the next experiment will be closer to the specified results.

11. It was suggested that the final criterion test and the posttests include many items in "essay" or sentence-completion or solution-working form. These items provide maximum information

and the most detailed data. But they also pose a major problem for the course management procedures, particularly from the standpoint of staff and time requirements. We can now consider replacing those items with objectively scored items, items that can be scored mechanically, possibly by computer. We recommend that you do this at this point only for those objectives that appear to have been effectively learned by a relatively large percentage of students. We still need that more detailed data on the objectives that are greater problems for our students and for us. You might consider 70% or 80% correct as your cut-off point here, or even 60%.

Multiple-choice, true-false, short sentence-completion items, and numerical answer items can be inappropriate in the same ways that we found some of the other items to be. They can be too easy, too difficult, ambiguous, misdirecting, and so on. Assume, until data indicate otherwise, that your present set of test items is adequate--valid, reliable, relevant, etc. If you replace one of those items you should replace it only by another item that measures the same thing.

Suppose that you identify a final criterion item that was judged to be adequate, to require no revision, and 70% of the students answered it correctly. The item requires a definition of a principle in terms of its application to a specific situation. What is involved in replacing this item with one or more multiple-choice items to test the same objective? We suggest that you prepare such items drawing on the expertise of a competent and experienced developer of such items. Have the multiple-choice items reviewed by other staff members and have them judge the equivalence to the original item. When the new items are acceptable on that basis, plan to use them and to *use the original item as well*. That is, each student who is given the new items will also be given the original item. In this way you will be able to determine whether the student who answers one correctly also is correct on the other one. You may not obtain perfect agreement, but the agreement between the new and the old should be very high if the two items are in fact measuring the same objective at the same level of complexity. Plan to use two parts for the test when you are trying out items in this way. Put all of the multiple-choice items in the second part, have the students complete the first part and turn it in, and then give them the second part. A multiple-choice item contains cues and information that might provide inappropriate assistance in answering the other question.

Consider the same approach for all of the posttests, since these have to be scored quickly and the diagnostic information returned to the students. As a means of saving some time and avoiding over-burdening the students on the posttests, consider the possibility of giving only some of the students both items, perhaps as few as ten if you are using large groups, and give the others only the original items. On each posttest use a different group of students for the double items, to distribute the amount of effort so that no student will be penalized as far as time requirements are concerned.

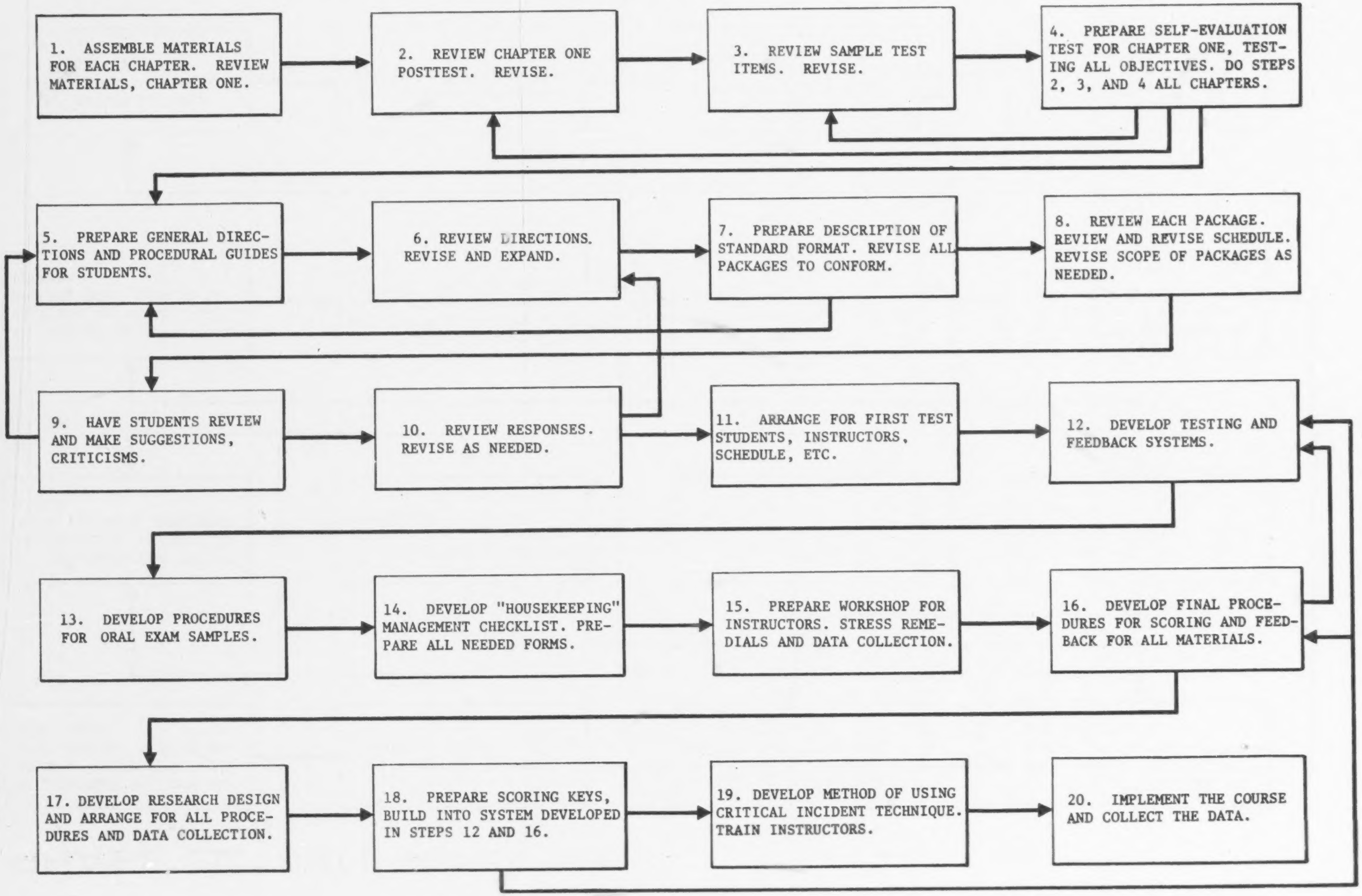
12. When you have completed all revisions to the course structure, materials, management procedures, tests, etc., review all of the materials. Be sure that the materials given the students--objectives, sample items, lists of resources, schedules, forms, etc.--are revised to fit into the surrounding changes. Revise forms as necessary to obtain better and more relevant and precise data. In short, review *the entire course in all of its facets* and make any necessary changes to make it a viable product.

Make all necessary plans for the second experimental tryout, include an instructor orientation and training session, the student orientations, and other preparatory procedures. Then conduct the second tryout, collecting data as before, picking up any pieces as you go, and attempting to learn as much as possible for your planning of the next revision. Repeat all of the steps in this section after each tryout, and develop and test your own procedures to add to those specified here. There are many techniques that have been developed empirically for special purposes, special problems, and special settings.

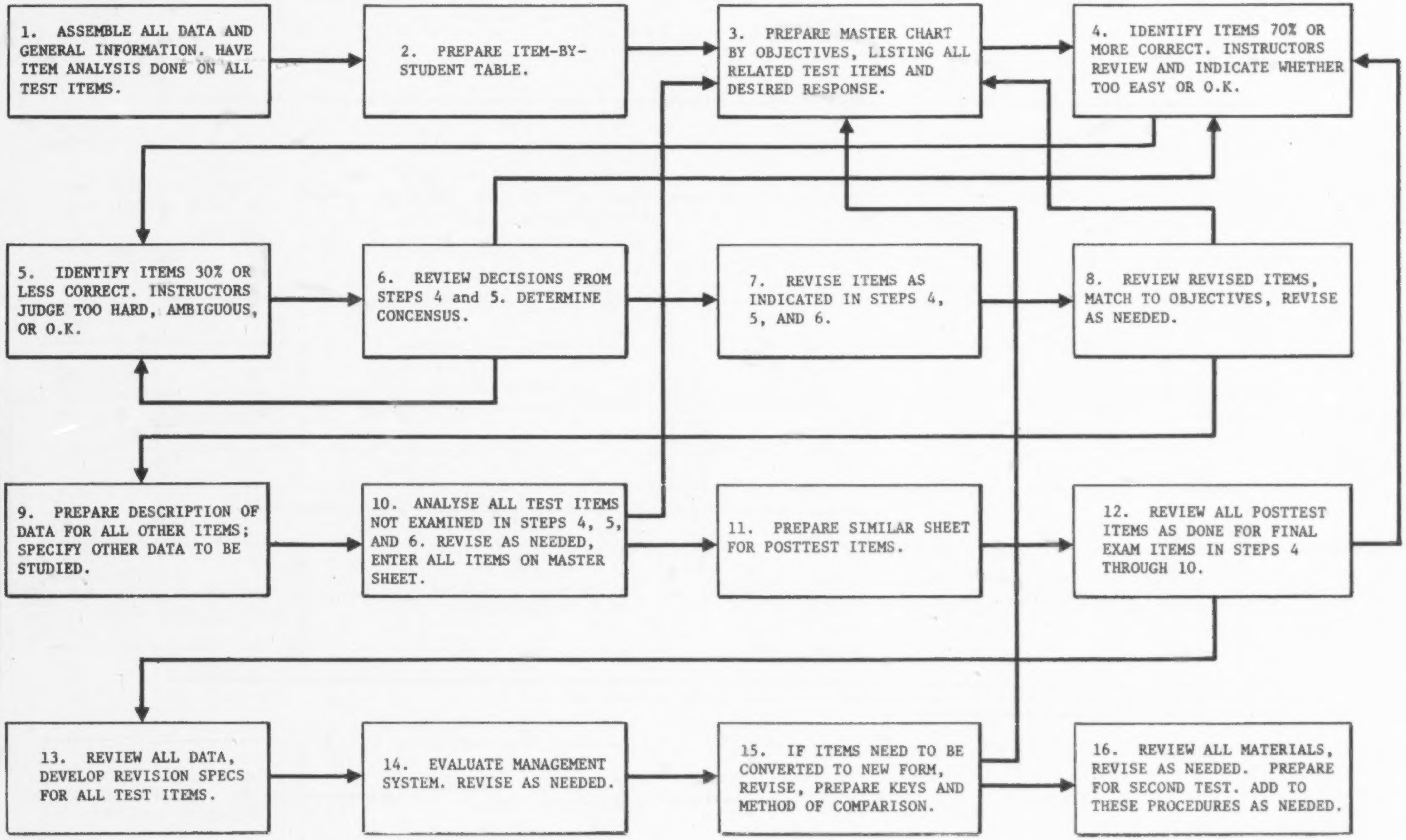
When you encounter problems for which you can find no apparent solution, obtain consultant support and assistance from individuals who have had previous experience with the empirical approach in operational settings similar to yours. They might have learned how to handle problems similar to yours, and might have developed--through much painful experimentation--techniques that you can use to good advantage.

Certain consequences will affect earlier steps or will require that those earlier steps be re-done. See the flowchart in Part D for indications of the recommended recycling that should be done systematically as these steps are completed.

# PHASE III *PART D* SECTION ONE


1. ASSEMBLE MATERIALS FOR EACH CHAPTER. REVIEW MATERIALS, CHAPTER ONE.
2. REVIEW CHAPTER ONE POSTTEST. REVISE.
3. REVIEW SAMPLE TEST ITEMS. REVISE.
4. PREPARE SELF-EVALUATION TEST FOR CHAPTER ONE, TESTING ALL OBJECTIVES. DO STEPS 2, 3, AND 4 ALL CHAPTERS.
5. PREPARE GENERAL DIRECTIONS AND PROCEDURAL GUIDES FOR STUDENTS.
6. REVIEW DIRECTIONS. REVISE AND EXPAND.
7. PREPARE DESCRIPTION OF STANDARD FORMAT. REVISE ALL PACKAGES TO CONFORM.
8. REVIEW EACH PACKAGE. REVIEW AND REVISE SCHEDULE. REVISE SCOPE OF PACKAGES AS NEEDED.
9. HAVE STUDENTS REVIEW AND MAKE SUGGESTIONS, CRITICISMS.
10. REVIEW RESPONSES. REVISE AS NEEDED.
11. ARRANGE FOR FIRST TEST STUDENTS, INSTRUCTORS, SCHEDULE, ETC.
12. DEVELOP TESTING AND FEEDBACK SYSTEMS.
13. DEVELOP PROCEDURES FOR ORAL EXAM SAMPLES.
14. DEVELOP "HOUSEKEEPING" MANAGEMENT CHECKLIST. PREPARE ALL NEEDED FORMS.
15. PREPARE WORKSHOP FOR INSTRUCTORS. STRESS REMEDIALS AND DATA COLLECTION.
16. DEVELOP FINAL PROCEDURES FOR SCORING AND FEEDBACK FOR ALL MATERIALS.
17. DEVELOP RESEARCH DESIGN AND ARRANGE FOR ALL PROCEDURES AND DATA COLLECTION.
18. PREPARE SCORING KEYS, BUILD INTO SYSTEM DEVELOPED IN STEPS 12 AND 16.
19. DEVELOP METHOD OF USING CRITICAL INCIDENT TECHNIQUE. TRAIN INSTRUCTORS.
20. IMPLEMENT THE COURSE AND COLLECT THE DATA.

# PHASE III *PART D* SECTION TWO


1. ASSEMBLE ALL DATA AND GENERAL INFORMATION. HAVE ITEM ANALYSIS DONE ON ALL TEST ITEMS.
2. PREPARE ITEM-BY-STUDENT TABLE.
3. PREPARE MASTER CHART BY OBJECTIVES, LISTING ALL RELATED TEST ITEMS AND DESIRED RESPONSE.
4. IDENTIFY ITEMS 70% OR MORE CORRECT. INSTRUCTORS REVIEW AND INDICATE WHETHER TOO EASY OR O.K.
5. IDENTIFY ITEMS 30% OR LESS CORRECT. INSTRUCTORS JUDGE TOO HARD, AMBIGUOUS, OR O.K.
6. REVIEW DECISIONS FROM STEPS 4 and 5. DETERMINE CONCENSUS.
7. REVISE ITEMS AS INDICATED IN STEPS 4, 5, AND 6.
8. REVIEW REVISED ITEMS, MATCH TO OBJECTIVES, REVISE AS NEEDED.
9. PREPARE DESCRIPTION OF DATA FOR ALL OTHER ITEMS; SPECIFY OTHER DATA TO BE STUDIED.
10. ANALYSE ALL TEST ITEMS NOT EXAMINED IN STEPS 4, 5, AND 6. REVISE AS NEEDED, ENTER ALL ITEMS ON MASTER SHEET.
11. PREPARE SIMILAR SHEET FOR POSTTEST ITEMS.
12. REVIEW ALL POSTTEST ITEMS AS DONE FOR FINAL EXAM ITEMS IN STEPS 4 THROUGH 10.
13. REVIEW ALL DATA, DEVELOP REVISION SPECS FOR ALL TEST ITEMS.
14. EVALUATE MANAGEMENT SYSTEM. REVISE AS NEEDED.
15. IF ITEMS NEED TO BE CONVERTED TO NEW FORM, REVISE, PREPARE KEYS AND METHOD OF COMPARISON.
16. REVIEW ALL MATERIALS, REVISE AS NEEDED. PREPARE FOR SECOND TEST. ADD TO THESE PROCEDURES AS NEEDED.

## SUPPLEMENT

The material that follows consists of a variety of supplementary items, supplementary to the procedures described in the main body of this document. The purpose of these materials is to provide a broader set of options and approaches, all within the same basic empirical course development model. Various empirical models have been developed and utilized in course development projects, and most of the models reflected the size of their respective budgets in their scope, complexity, implementation requirements, and other aspects. It is possible to adapt an empirical model--including materials selection or development--to almost any size budget, and almost any set of resources, including staffing.

Many of the directors of large scale individualization projects in ongoing system operations have indicated that by appropriately re-allocating resources, their projects could have been executed without funds beyond their normal and existing budgets. Those directors who have so stated have also indicated that this would be possible only "if we knew then what we know now." In other words, through several years of experience, they have developed empirical models that served their needs, and some of them did it with large budgets and resources, while others did it on a relative shoestring.

The model described here can be employed in minimum form, or as a base for a major developmental and/or research effort. The minimum components are the criterion test items and objectives, progress evaluation, remediation, and the iterative tryout and revision process, including the analysis of actual results in relation to the intended results. Many of the general procedures described in the basic model provide the possibility for many options in materials and instructional methods. This Supplement does not attempt to present all possible options, but does describe several that have been developed and utilized within the basic model. Additional information is also included which will be helpful in providing staff orientation.

PAGE

Paper I. Diagnostic Practice Exercises....................... 76

Paper II. Programmed Text Materials........................... 79

Paper III. Student Tutors ..................................... 82

## PAPER I. DIAGNOSTIC PRACTICE EXERCISES

Between the assigned study activities, a variety of materials can be added to provide additional progress evaluation and practice. Several kinds of materials were tested for this purpose as part of the Naval Academy Physics Project. One early set of materials took the form of a "Study Guide" which was designed as a branching program with multiple-choice questions. A student selects his answer, and records it on either a responsive answer sheet (chemically imprinted) or a device very much like a punchboard. These answer mechanisms serve two purposes: the student's response is recorded for use in later data analyses, and immediate feedback is provided to the student.

In the first versions of the Study Guide, the feedback information was an indication of the page that the student was to turn to next. Upon turning to that page the student was told whether or not his choice was correct; if incorrect, he was given some additional information, either about that incorrect choice or some additional guidance designed to assist him with the problem. He was then directed back to the problem and was directed to try again. A searching examination of the data showed that this "remedial" correction was no more effective than a simple "hint" given independently of the incorrect answer chosen. The incorrect alternatives in each question were designed intuitively, on the basis of subject matter experience and expertise using assumptions about the kinds of errors that students might make. This is the standard procedure for the design of branching programs. But testing then typically indicates, as it did in the Physics Project, that some of the choices are not selected at all, and that the discussion of the wrong answer does less than necessary to clarify the correct answer. The "remedial" branches did very little to improve performance.

A different kind of structure was developed for the Study Guide in the final version of the course materials for the Physics Project. The Study Guide contains the responsive answer sheets and identifies the learning materials. The problems, feedback material, and the information panels were put into a separate booklet identified as "Problems and Solutions." Multiple-choice questions were used primarily for verbal material, and problems requiring a quantitative answer called for the number and unit of measure to be written. The student, using a special pen, then marks a box for a multiple-choice, or a larger box under his constructed response. In the case of constructed response answers, the correct word or phrase appeared in the special box. In the case of multiple-choice items, a response marked in an incorrect box reveals an "X". The student must eventually choose the correct answer, and mark the corresponding box which reveals a page number. This feedback page provides the student with a full explanation or solution. In other words, there is no remedial branching; an incorrect response is identified as being incorrect, but all students, after responding correctly, are sent to the same feedback page. The feedback page contained a description of the correct solution, with emphasis on the discriminations that the student had to make, the selections and actions he had to take, and the method of arriving at the correct answer. This emphasis on the correct answer, and why it is the correct answer, is more useful than the simple identification of a wrong answer as wrong, with additional discussion of why the choice was not acceptable. In some cases highly probable errors were also discussed, contrasting the incorrect with the correct answer. But the most useful kind of information is clarification of the correct answer.

This approach it will be noted, makes it unnecessary to prepare a different branch for each answer choice since all students proceed directly to the feedback page after recording their responses. The feedback pages are "scrambled" in the sense of being arranged in a sequence that does not match the page number sequence, and a feedback page does not identify by number the problem it discusses. This is not a foolproof way of forcing the student to commit himself to a response before reading the feedback information, but it does make it far more convenient for him to follow the specified procedures than to search for the feedback information. It should be noted also that the feedback page does not simply state the correct answer--which provides little remedial instruction--but "walks the student through" the method of arriving at the correct answer, discussing each step in the process.

The procedures for developing such practice materials, with feedback, are quite straightforward.

1. The Study Guide, in this design, contains all of the general and specific information made available to the student: the student objectives, the sample test items, the list of options from which he is to choose his study, and other relevant information discussed previously. Each Study Guide is (depending upon the kind of scheduling involved, free-running and self-paced, or group scheduled) designed for one chapter, unit, or week's assigned work. These materials have already been assembled.

2. Certain options are available at this point. The self-evaluation test can be bound into the Study Guide for continuous reference. If, in fact, this is to be done, the sample criterion items can be modified or eliminated. For example, since the self-evaluation test does cover all of the objectives, the sample items might be unnecessary. If, in the self-test, smaller components of the objectives are to be tested, then the sample criterion items should also be included showing the student the more complex level at which he must perform on the posttest. This would be the case, for example, if the posttest items were problem-solving tasks requiring "chains" of responses using several sub-objectives. If the self-test deals with each of the steps as separate items, then two different levels of complexity are involved, and both kinds of items should be included; the sub-objective items in the self-test, and the more complex items in the posttest. This will depend largely on the nature of the subject matter and its objectives.

   We recommend that the self-test *not* be bound into the Study Guide, on the basis of management considerations. An alternative is to have the student complete the practice problems in order to obtain the self-test. This means that relevant data, in the form of the answers, will systematically be collected for use in later revision procedures. While the course "materials or resources librarian" could collect the responsive answer sheets and distribute the self-tests (and the responsive answer sheets to accompany the self-tests), it is recommended that the student's sponsor be the one assigned this task. Unless a sponsor has a large number of students assigned to him, the task is not burdensome, and it provides an opportunity for the student and sponsor to interact. This forced contact is useful, and the student might not otherwise go to the slight trouble of consulting his sponsor prior to taking the self-test. Obviously, this contact should not be made aversive by the sponsor, but should direct itself to management or learning problems.

If you decide to add the self-tests to the Study Guides, specify that procedure, and indicate the location of the self-tests in the Study Guides. If you decide to have the sponsors distribute self-tests as students turn in the practice problem answer sheets, then you need to develop a simple check list for the instructors to follow, indicating such things as scanning the answer sheets to identify trouble spots, and asking the student if he wants help, asking questions to discover the source of difficulty, etc.

3. Do not restrict yourself to multiple-choice questions simply to make use of some form of responsive answer sheet or card. If you plan to use a commercially marketed form or device, develop an alternative method of providing feedback for completion or "essay" questions, since you will almost certainly want to use various kinds of questions.

   Prepare the practice questions, problems, and practice exercises. Then prepare the discussions of the correct answers. Add discussion of highly probable errors *only* if you have considerable confidence--and data if possible--to indicate the nature of highly probable errors and misinterpretations. Arrange the problems and questions in sequence in the first part of the Problems and Solutions booklet, and "scramble" the discussions in the second part of that booklet. At the end of each discussion add an additional question to be answered, again with the answer to be indicated in the Study Guide. This provides the opportunity for the student to practice using the additional information immediately after the deficiency has been, hopefully, removed.

4. Develop the answer sheets for the practice materials, have them produced and made a part of the Study Guide. Review the Study Guide and, if possible, have a student read through Study Guide Number One in its entirety just to see if it is all clear and seems to include all of the information and directions that are needed. Review again to be sure that the answer sheet sends the student to the correct feedback page for each question in the Problems and Solutions booklet.

# PAPER II. PROGRAMMED TEXT MATERIALS

The development of linear or adjunctive programmed materials is not recommended at the local level unless well-trained and experienced programmers are available on the project staff. It is very easy to develop materials that *look* like programmed materials, particularly like programmed text materials produced during the early 1960's. The trend then was to develop programs as a series of small steps (frames) usually no more than one or two dozen words in length. Generally each frame contained one or more blanks on which a word was to be written, in sentence completion form. The underlying principle, that each step should be small, was generally distorted into the use of too many steps that were too small, requiring little thinking, and providing practice in small but non-cumulative increments.

Thousands of programs of this sort exist, even though the programs and the techniques that produced them are obsolete! Current thinking has it that each step should be as large a step or increment as the student is likely to be able to complete. And direct questions are used as much or more than the fill-in-the-blank response requirement. And frequently programs have been developed without any application of the analysis and design technology that is necessary to produce high quality programs that are both effective and efficient. Programs of that sort are written to look like the small-steps-with-blanks kinds of programs, but the appearance is not as important as the methodology that produced the materials.

The development of programmed text materials is time consuming and expensive. This is not to say that it is not worthwhile, but frequently effective and high-quality programs have already been produced and can be obtained without all of the developmental time and expense. Some programs worth considering for use have been published commercially, and many are available from projects funded by the U.S. Office of Education, materials which are then in the Public Domain. It is worth checking with the Office of Education and with the staff of projects that might be able to provide already validated programs at little or no cost.

The selection of appropriate programs has been discussed in the body of the model. Matching of objectives is the most critical step, in order to select programs that were designed and validated on students similar to yours, and dealing with equivalent objectives.

1. Compare the stated objectives of programs under consideration with your own objectives. Examine the data accompanying those that seem to match your objectives most closely. If the data appear adequate, select the three or four that seem most appropriate for each set of objectives or major topics.

2. Have several of your instructors examine the programs from the subject matter point of view. Have them identify the best two, on the basis of technical accuracy and completeness of coverage. Don't let them evaluate on the basis of their estimate

of how well the programs will work--the data tell you that--or how dull or interesting they think the students might find the programs. Identify the two which the concensus indicates are most appropriate.

3. If possible, have several test students proceed through the programs, and administer a criterion test. (You might have to develop your own for this purpose, or you could use a combination of some of the program's test items and some of your posttest and criterion test items). Also ask the students (either informally, orally, or by filling in a questionnaire prepared for that purpose) to tell you how well they liked the program, how interesting it appeared to be, and how efficient it appeared to them. If one or both of the programs is acceptable, add it to your list of resources. If neither appears acceptable, find out if instructors and your test students think that it is worth using to help students in spite of weaknesses. Reject them if there are no redeeming qualities.

4. Decide how the programs are to be used; as optional study or remedial materials, assigned as required remedial, etc. Add the necessary specifications.

5. If the programs seem to do an adequate job of providing instruction for some of your objectives, but not all objectives in a given cluster--which will often be the case--this should be indicated for the students. That same information should also be provided for the sponsors, so they will not be likely to assign the programs or suggest their use, assuming that the programs will accomplish more than they actually can. Determine this from the published data and from your own test use of the program. Prepare the necessary information sheets.

6. The programs that you have selected will already have been tested and revised--you will remember that you were advised earlier not to consider using any programs that do not have objectives, validation information, and data. But you should collect the programs or the worksheets so that frame-by-frame responses can be analyzed. The results will be valuable data for the author and publisher, and you should make contacts so that the data can be delivered. The results will also help you prepare supplementary materials to improve the programs yourself. Develop procedures for collecting the frame responses, and the program posttests from all students. Prepare the procedural guides for preparation of the program posttests and their use and collection.

7. The analysis of the results should follow basically the same procedures described in the body of the model. Identification of weak portions of the program will be relatively easy, revision decisions will be more difficult. It is suggested that

you not attempt specific changes to the program unless a competent programmer is available. Supplementary materials, however, can be prepared in the same form as the practice materials described in Paper I of this Supplement.

## PAPER III. STUDENT TUTORS

A resource that is available for instructional purposes in large quantities is the student group itself. Students study together, help each other, and work toward comprehension together. Sometimes students work toward objectives together, and sometimes a student who has already achieved an objective provides assistance for other students who are in trouble and need help. Although lacking the experience and the degree of subject matter sophistication that the instructors possess, students--as tutors--share the flexibility that is perhaps the instructor's greatest strength. Unlike any text or audiovisual material, the tutor can attempt to adapt to the student and be responsive to him.

Students who are part of the same student group as the tutees are generally referred to as "peer tutors," while students who are advanced--say, those who have completed the course in question and have gone on to advanced courses--are referred to as "cross tutors." Either may be considered for utilization, and almost all of the considerations and procedures described below apply both to peer tutors and cross tutors.

As a basic rule, it is suggested that you do *not* use tutors by simply telling a student who has already achieved an objective, "Go teach that objective to that student." With no more guidance than that, the experience will be largely trial-and-error, and could be unsuccessful and unpleasant for both the student-tutee and the would-be tutor. There are two basic requirements for the use of student tutors--or for that matter, for the use of instructor-aides of any kind as tutors. First of all, the tutors will require some training; they will have to learn certain techniques. Second, they will have to have some materials, some basic structure to follow.

Ideally, the training to be provided should be designed, developed, and administered within the structure of the same basic model described for the course development itself. Objectives should be identified, instruction--preferably interactive instruction--should be provided, and the course should be tested and revised until the desired behavior does occur.

A set of specifications for such a course has been prepared under contract to the U.S. Office of Education (Deterline, 1971). The basic procedures are based on findings of several successful research and development projects. The tutoring procedures taught in the course consist of the tutors using test items and student responses to those items for remedial tutoring. The tutor attempts, by asking questions, to diagnose the student's problem and identify the cause of each incorrect response. Since tests, homework, and other practice materials can be used, no special tutoring materials have to be produced, and both management and tutor training are relatively easy to accomplish.

One of the more critical parts of any instructional enterprise is the problem of individual differences. Accountability emphasizes the importance of identifying problems as quickly as possible, and providing remedial instruction and additional elaboration and drill and practice for those students who need it--preferably on an individual basis. The instructor sometimes faces more remedial needs than can be met, particularly as students encounter trouble topics. In the conventional classroom and course setting, group scheduled, instructor-centered, and norm referenced, there is sometimes no diagnostic-remedial procedure of any kind. It would appear that student tutors, either peer-tutors or cross-tutors, could provide considerable assistance as a supplementary resource for the instructor to utilize. In what follows, it is assumed that all initial instructional functions will be provided by or managed by the instructor; the tutors are employed for a variety of follow-up purposes as specified and delineated by the instructor.

1. The first decision to be made is the choice between peer- and cross-tutors. Although there is no reason why both cannot be employed in the same setting, there are considerations and requirements that must be taken into account. For example, if cross-tutors are to be used, a coordinator or manager is generally required since the cross-tutors are generally physically removed from the location of the tutees; they must go from one location to another, and the scheduling of tutor activities must be accomplished within whatever other schedules control the activities of tutors and tutees. In some settings, these management functions are so complex as to be almost impossible. The problems of scheduling are much less critical in a college or university setting, and are probably most severe when both tutors and tutees are high school students.

   There are advantages to peer-tutoring that are lacking in cross-tutoring, and vice versa. For example, the peer-tutor will generally only recently have achieved the objectives which he will be tutoring while the cross-tutor will possibly be less able to view the objective from the position of the student. On the other hand, the older, more advanced student will generally have greater verbal skills, and perhaps greater competence in discriminating and identifying sources of difficulties. It is suggested that if the scheduling and management problems can be resolved, the first approach to the use of students as tutors be cross-tutoring. Explore the local constraints, scheduling, and management problems, and make the appropriate decision.

2. Develop a set of objectives (performance specifications) describing the kinds of procedures that the tutor is to carry out. The first half of the set of procedures will be general, in the sense of having the trainee (the students being trained as tutors will be referred to as trainees to avoid confusion between the tutors, the tutees, and the tutor-trainees) describe and demonstrate procedures for establishing rapport, identify and confirm correct responses, identify incorrect

responses, formulate and ask questions designed to direct the student's attention and structure his approach to a problem. The course of instruction designed for the trainees should be more than a lecture presentation of suggestions. The instruction should be interactive, and the trainees should be active throughout, describing and demonstrating. Ideally, role-play should be utilized to allow the instructor to demonstrate and to allow the trainees to practice and receive immediate critiques of their work. A balance must be struck between the instructional requirement of developing the minimum performance skills in the trainees, and the amount of time required of them. If, for example, volunteers are sought for a cross-tutoring project, and the would-be volunteer discovers that training will consist of evening classes, particularly if more than a few hours are involved, a high dropout rate can be expected. The training must be as convenient, enjoyable, and efficient as possible. You will also have to consider the reward structure in which the tutor is to operate. Some tutors will find the activity itself very rewarding, but other potentially effective tutors will require something more. For considerations relevant to this point, see *Contingency Management in the Classroom,* by Lloyd Homme, Research Press, P.O. Box 2459, Station A, Champaign, Illinois 61820.

The brief course need not be elaborate. The objectives may be limited to the procedures listed above. Additional information to be presented should be limited to such topics as the interaction typical of a tutorial, the need for individualized remedial assistance, confirmation and correction. The remainder of the course should concentrate on having them practice the questioning and prompting procedures. It should be stressed, and the practice and role-play should encourage, guide, and provide feedback to support an emphasis on the tutor as a *questioner* rather than a *lecturer*. The trainees should practice tutoring each other, and should tutor actual target students, observed by the instructor. It is not recommended that the trainees practice with actual students before a group of fellow trainees, because of the student-tutee's possible reaction to the situation. One point to be stressed, both in the information presented, and in the instructor and trainee demonstrations, is to avoid lecturing, or at least to minimize explanations, and to emphasize prompting and guiding the tutee. This includes attending to relevant features of the environment, problem, etc., and being helped to respond appropriately. Relevant discussions of prompting, while avoiding over-prompting, are available and are recommended: see *Good Frames and Bad,* by Susan Markle. Design the course in terms of its objectives and practice sessions. Leave the final form for adaptations depending upon characteristics of the students who are to be used as tutors.

3. Generally the better students in any grade will have time available that need not be spent in their own work. There is an exception to this in the student who is a high-achiever but who expends considerable time and effort. Students considered as tutors should be those who do have the time available and who indicate considerable interest in taking part in the tutoring project. While verbal skills are necessary, some students who are highly verbal will also show a tendency to talk too much, inhibiting rather than encouraging the tutee to respond and be the more active of the two. Especially during the early phase of the use of tutors, the instructor(s) will have to observe, provide feedback for the tutors themselves, and possibly, screen out those tutors who are not successful. Not every student (or teacher, for that matter) will necessarily be able to develop skill at tutoring. Make the initial selection of the tutor-trainees.

4. Considering the characteristics of the tutors--their grade level, competence, etc.--develop the semi-final version of the training course. The nature of the material to be used remains to be incorporated; that step is next.

5. Review the kinds of material that might be used in the tutorial setting. We have already indicated that the tutor is not to be used to attempt the original teaching; that remains the function of the instructor or supplementary materials assigned by the instructor. Two functions are suggested for consideration: drill and practice, or practice exercises; and remedial review of test materials, or completed homework. The basic difference between the two is that the former comes between the teaching and the testing, and the latter follows testing or homework or other activities that have been completed. The second function is more a remedial activity than is the first.

   Whether practice materials are to be used by and with tutors or not, the remedial tutoring function can be of great assistance to the students who are encountering difficulty. In a course of the kind described in the main section of the model, there will be posttests, student self-tests, practice problems and exercises, possibly homework assignments, and possibly additional tests for review, periodic progress evaluation, and other purposes. Tests and exercises and homework, in the present context, all have a relevant feature in common: the student, on his own, has attempted to apply what he has learned to questions, problems, or task assignments. These attempts produce results that can be evaluated to identify problem areas. Sometimes the detail required in an answer or solution is complete enough to identify the nature of the misinterpretation or lack of initial comprehension. But sometimes the response does not provide much information about the nature of the difficulty. A scoring key must be prepared for each question, problem, or task, helping the tutor attend to critical components and look for critical deficiencies. This is unlikely to be accomplished intuitively or on the basis of a logical design drawn from experience. The scoring key and guide should be developed empirically, by the instructor acting as the tutor and recording the tutorial sessions. This requires more time than many instructors feel is necessary, assuming that their experience with similar objectives and students provides adequate background for the development of accurate and adequate scoring keys, diagnostic guides, and other helpful procedural guides for the tutors. Intuition and judgment are sometimes correct, but sometimes incorrect and inadequate. If the empirical determination of requirements is possible, then there seems little justification for using a method more prone to error and omission. The instructor, by tutoring students, using the response records of tests, practice exercises, etc., can identify the kinds of problems that appear and determine the more effective methods of identifying and correcting those problems. The techniques can then be developed as procedural guides for the student-tutors to follow. Identify the tests, exercises, and other materials that require responses by the students, develop a tentative set of guidelines, follow them as you tutor several test students. Then revise the guidelines.

6. Develop practice exercises and demonstrations for the tutor training course, to teach the trainees how to use the guidelines. The guidelines should provide procedures, directions, and guidance for the trainees.

7. Prepare the final version of the course of instruction, and make arrangements for all activities previously designed--such as the scheduling of students as subjects for demonstrations and practice tutoring.

8. Arrange for at least four students to be assigned to the course as trainees. Conduct the course. If any of the guidelines appear inadequate, revise them on the spot, and have the trainees participate in the revision. Keep the course flexible, and provide as close observation and continuous feedback as necessary. Do not simply run the course and hope for the best, do whatever seems to be necessary to impart the necessary skills. As changes are made, keep the documentation up to date so the course can be revised. Evaluate the course, not by subjective evaluations of observed activities of the tutors, but by the identifiable effects on the tutees. No matter how skillfully the tutors seem to be tutoring, the important result should be effective remediation, measurable in the performance capabilities of the tutees.

9. When the course has been revised and appears to be able to achieve its objectives, use the course to train the number of tutors that you have determined to be necessary.

10. Student tutoring like all other components of instruction, must be effectively managed. The tutees should be given a test of some sort, possibly in discussion form, by the instructor. Also, each tutor should prepare a short report on each tutoring session indicating the items or problems covered, and the tutor's evaluation of the results. The instructor should refer to the records during his follow-up meeting with the tutees, and should also meet the tutors and discuss their efforts and the instructor's evaluation. The instructor should periodically sit in on tutorial sessions to observe and provide additional feedback for the tutor. If this is not done, the tutors will possibly begin to skip some of the steps and ignore some of the guidelines. Develop the management guidelines, scheduling procedures, report forms, scheduling procedures for instructor follow-ups and spot-checks, etc.

11. On the attitudinal side, the tutors must be encouraged to view their tutees as their charges, as individuals who are to be dependent upon them for personal support and encouragement. Frequent meeting with the tutors as a group should emphasize this relationship. Unless absolutely necessary, tutees should be assigned to one tutor and not shifted from one tutor to another. In addition to the instructional support that each tutee receives, the tutee will have a tutor who indicates that he cares and is interested in the tutee. This can be vitally important to a tutee who views himself primarily as a failure, and who is in fact, more often a failure than a success as a student.

12. There is some evidence to indicate that tutor-tutee pairs consisting of two students, neither of whom has achieved the objectives being worked on, can be effective, but this approach should be considered only as a research and development effort, since very little is known about the efficacy of the approach or the procedures that must be utilized. Also, one danger of using peer-tutors from the same classroom group is the possibility of the tutors being stigmatized by other students. One political expedient that is possible when programmed text materials are available is to use the programs in a tutor-tutee setting, with the confirmation being under the control of the tutor, who does little else but provide the confirmation or identify errors. When this is done, even the poorest students can be used as tutors at some time or another, in some subject. In this way all students are used as tutors, and the better students will then not suffer for being singled out. If peer-tutors are to be used, develop the necessary procedures for

providing an opportunity for all students to do some tutoring, within their levels of ability to do so.

13. The procedures described so far are designed to be used with the results of tests, homework, workbooks, practice exercises, etc. It is not always necessary for the instructor to wait until such performance records have been obtained. There are many other indications of student difficulty that an instructor will be able to observe. As the initial information is presented, the instructor will often be able to observe indications of confusion and lack of comprehension. When this is the case, tutors can be assigned to those students who are in difficulty to help them in practice exercises, workbooks, and other materials.

    If there are no such materials available, then the tutor might be able to discuss the objectives, sample items, and information panels with the tutees, asking questions in an attempt to discover topics of difficulty or confusion. Here again, the tutors work around materials of some sort, rather than providing some form of extemporaneous tutorial presentation. Tutors can also assist as students read the available materials, whether conventional textbooks, programs, or audiovisual materials. The reports submitted by the tutors should be structured so that if a tutor cannot identify the exact nature of the problem, he can at least record a description of what seems to be the main topic on which difficulty has been encountered. This will do a great deal of the screening that a sponsor must do in order to identify the problem and problem area. If tutors are to be used in this fashion, to facilitate learning prior to the individual work on tests and other materials, develop the tutorial procedures for this approach, the necessary records and additional instruction and guidelines necessary.

14. Add to the management procedures, if necessary, to provide management of tutors for the purpose described in the preceding step.

15. If student tutors are to be used, it is wise to arrange to have a few more tutors trained and ready to work than anticipated requirements specify. As trouble topics are encountered, as tutors become sick and miss school, and as a number of variables shift the tutoring requirements up and down. It is better to have enough tutors available to handle the peak loads than to structure a course with too few tutors.

    If at any time the need for tutors is relatively small, the surplus tutors can volunteer for other activities as well as tutoring. The more highly individualized the course, the greater the need for clerical work of all kinds, particularly if a computer is not available, or if the course is still under development and the management system has not yet been put on the computer. The tutors, working closely with students, also tend to develop a student's view of the course and related materials. They can function effectively as consultants to the project staff involved in revising and improving the materials, and some might participate effectively in the revision of the materials. Obviously, the tutors should not be used for work that should more appropriately be done by the project staff. They should not simply be assigned all of the "busy-work" and dull "dirty work." Additional, non-tutoring work should be volunteered for, and you should consider paying student-tutors for additional work, and possibly for their tutoring jobs. They are, after all, students doing instructional tasks, and payment for such work would not be inappropriate. Determine how the tutors might be used for other activities, how their work would be managed, and how a payment schedule or other reward system should be established and implemented.

## PAPER IV AUDIOVISUAL MATERIALS

It is suggested that any audiovisual materials to be included in a course of instruction be made interactive; that is, the student should not simply listen and observe in a relatively passive fashion. The materials should get the student involved in interpreting the information as it is presented, applying it, and in other ways responding to it. One method of doing this is to program the presentations, utilizing some of the methods described in "Programmed Instruction," *National Society for the Study of Education Yearbook,* 1967. The same problems referred to in Paper II of the Supplement (description of the development of programmed materials in text form) apply here. The more precise the series of frames or steps in the program, the more expertise is required to develop the materials. A simplified program, in the form of a series of questions inserted in a presentation aimed at objectives, is a possibility, and the iterative process can make such a sequence work. The process for developing programs in this way is basically the same whether original materials are being used, or published materials are being modified. You might consider the development of original materials in this way, using the techniques described below for adapting available materials.

The following procedures apply to any form of instructional materials, but are included here primarily in relation to adding audiovisual materials to courses under development. The procedures also apply to audio tapes, with or without printed or projected visuals, slide/tape presentations, videotapes, and sound motion pictures. The project staff can conveniently prepare audio tapes for a variety of purposes, some of which were described in the body of the empirical development model. A reference that will be useful if audio tapes are being considered is "Audio Tape Cassettes in Classroom and Carrel," *Sound Education Reports,* Los Altos, California, which describes the use of audio tape for procedural guides and instructional materials.

Typically, commercially available materials are designed as a continuous flow of information, verbal (usually in audio form) and visual. The student's activities are not guided--although his attention might be--and the student can watch and listen casually. Also, most materials of that sort do not specify the objectives to which they address themselves, do not provide a posttest, and do not provide worksheets, note-taking guides, or any supplementary material to help the student get the most from the presentations. Students do learn some things from such presentations, of course, but unreliably, inconsistently, and less effectively than they should.

There are basically two ways in which active student responses can be added to a presentation: one, a series of responses to be made during the presentation, and two, a series of responses to be made at the end of the presentation. And, of course, both methods can be used together. The series of responses to be made during the presentation could take the form of note-taking, perhaps within an outline form, or a series of questions or problems could be inserted. Some responses of this sort could be made by the student as the presentation continues, but others require that the presentation be stopped to give the student time to respond.

Some instructors object to the idea of stopping an audiovisual presentation to provide for student responses. In most cases there is no valid reason why this could not be done, unless it would in some way damage the equipment, which should not be the case. If the flow of information is actually one continuous topic on a relatively small objective, and if stopping could disrupt the continuity, then another approach might be considered. A set of questions or problems can follow the presentation requiring the student to apply as much of the information as he can remember. This second method is easier to apply and manage, but is most effective with relatively easy objectives or clusters of objectives.

Many audiovisual instructional presentations are apparently designed to be used as one component of the "redundancy approach" described earlier; that is, it is not expected that students will necessarily learn anything specific from the presentation, and certainly not everything presented. It is expected that the presentation will clarify certain facts or concepts and contribute to the total learning of the students. Materials designed for that purpose usually concentrate on clarity and immediate comprehension, but do not provide for guided active responding. A student might attend to a presentation, comprehend everything presented as it is presented, but be unable to recall enough to answer a complete set of questions given immediately after the completion of the presentation.

It is sometimes possible to determine whether or not it is appropriate to cluster the response requirements in a posttest. If, for example, the presentation deals with a trouble topic, or if considerable discrimination and recall of details is required, then possibly the posttest method would not be as effective or efficient as stopping the presentation at critical points to allow the students to respond immediately. Because the posttest method is easier and more convenient, it is suggested that it be used when it is acceptable. The empirical approach should be used, initially by attempting the posttest method, trying it out with several students, and then deciding on the basis of data and evaluations, whether that approach is feasible, or whether the other approach is necessary. In either case, students should be given descriptions of the objectives covered by the presentation, a note-taking guide or outline, and either sample test items or preferably, the posttest itself. Students should be permitted to study the posttest prior to the presentation, but should not be permitted to complete it during the presentation, since that disrupts attending.

The selection of existing materials is initially a process of comparing audiovisual content with course objectives. The subject matter specialists select those that best match objectives and appear to be clear, accurate, and adequate in the sense of completeness, relevance, etc. Here again, however, the judgments made by non-students must be confirmed by students. Initially, test students can be used to review the presentations and evaluate clarity, communication, and interest value. Later, as in the case of all other instructional components, the instructional effectiveness must be evaluated and appropriate actions taken on that basis.

The approach described here is extemely simplified, tied to objectives, and then subjected to the iterative, empirical formative process. It is suggested that these simplified procedures be used as the basic media selection and implementation procedures, but that more complex methods also be explored. Two works that discuss media design and selection methodologies within an objectives and empirical course development frameswork are: *A Behavioral Approach to Instructional Design and Media Selection,* by Donald T. Tosti and John R. Ball, (1969), Westinghouse Learning Corporation, 100 Park Avenue, New York, N. Y.; and *Instructional Media,* by Leslie J. Briggs, (1967), American Institute for Research, Pittsburgh, Pennsylvania. Experimentation with media as part of empirical course development can effectively utilize many of the approaches and much of the philosophy of these two reference works.

1. The nature of the objectives will determine some of the media selection considerations. One criterion for the Naval Academy Physics Project was the relevance of motion as a characteristic of a phenomenon. Motion was considered to be a relevant stimulus feature when seeing the actual process in motion facilitated learning. For certain other subject matters, motion would not be a relevant consideration.

   Another criterion is the "picture worth a thousand words" situation. Although this is not a universal principal, it does sometimes describe a stimulus complex that is more appropriately visual than verbal. It is generally more efficient to show an unfamiliar object or event than to attempt to communicate entirely through the use of words. A combination of visuals and descriptive words are recommended when the words can be used to direct visual attention to certain critical features. All courses should be examined with an eye to identifying possible uses of visual demonstrations or visual representations that might facilitate communication.

   It is helpful to proceed in this fashion: identify those objectives which are facilitated when the student has a visual representation before him. Examine the instructional material and identify each set of information that "paints a word picture," describing a physical object, event, or process without an accompanying visual being provided. A student, reading or hearing the information must, in effect, create a mental picture as he receives the information. Any slight inaccuracy in the composition or structure of that picture can provide a basis for confusion, misinterpretation, and other kinds of errors. Review all materials and identify the following:

a. objectives for which demonstrations with motion would appear to be "essential" or merely "helpful."

b. trouble topics for which an audiovisual presentation or live demonstration would appear to be helpful. Depending on the structure of the course, it could be far more economical and practical to provide the live demonstration rather than to obtain an audiovisual presentation. Of course, the opposite can also be the case.

c. instructional materials in which the "mental picture" problem could occur. For each example, determine whether color is a necessary stimulus feature. If not, a black and white photograph or drawing might be adequate.

d. unifying objectives for which an audiovisual presentation might help students interpret and respond to other, related information.

Now review all of the specifications developed in steps a through d, and identify any examples for which a two-dimensional audiovisual presentation will simply not be adequate. For those examples, the object or process itself might have to be made available, possibly in a laboratory exercise. Practical problems involved in providing "hands-on" activities and physical access should be identified and resolved at this time.

2. You have now identified objectives, sub-objectives, or clusters of objectives for which some form of audiovisual presentation appears appropriate. You should not yet concern yourself with media selection in terms of the presentation devices or methods. We must first make decisions in terms of stimulus content. The only exceptions are the identification of the need for motion or color. If motion is required, printed pictures, slides, and filmstrips will not do; live demonstrations, videotapes, and motion pictures will have to be considered. And when color is critical, black and white materials, whether printed or projected, will not be adequate. But if color is not essential, the possibilities are vastly increased.

Generally it is desirable to provide visuals, for example, in the most inexpensive and easy-to-use form. A picture in a reference book will generally work as well as a projected slide, without requiring equipment. The primary concern should be the stimulus content; the temptation to use more elaborate equipment than is necessary should be avoided. Describe in general terms the content of the audiovisual presentations in relation to the objectives that you have identified. Specify what the student should see or hear in order to help him respond to the objective. These specifications will serve as a guide to help you identify relevant audiovisual materials as you review those available.

3. Obtain publisher and library lists of materials available that might fit your requirements. Compare the descriptions with your specifications and obtain more detailed descriptions if necessary. Identify those materials that appear to be relevant and arrange to review them; do not commit yourself sight unseen to any item. Review the material and select those that present the relevant information and are as unambiguous and as clear as possible. This is still a tentative decision.

4. For each item selected, determine whether there are any equipment problems that make the item more inconvenient than warrented its potential value. Develop a rough set of guidelines for using each item, storing the materials, making them available, and specifying how the student is to make use of the materials. If any of the procedures appear to be too cumbersome or inconvenient, consider rejecting the item. At the same time, consider the importance of the materials in helping the students attain their objectives. If an audiovisual item deals with a trouble topic, and appears to be potentially very helpful, you should make every effort to develop a practical method for using the material. If data should indicate later that the material is not as effective as had been hoped, it can then be discarded or replaced. Obviously, budget constraints must be considered at this time and necessary compromises made. Make the final selections.

5. Identify the audiovisual materials in terms of one of three categories: one, those dealing with relatively simple sets or clusters of objectives for which posttest responding appears appropriate; two, those dealing with more complex objectives for which a sequence of response requirements needs to be built into the presentation sequence; three, those that cannot readily be put into either of the other two categories, but straddle the two.

   Prepare the posttests for category one first. Review the content, the objectives, and criterion test items to be sure that you are viewing the materials in terms of the desired end product, because that is what your posttest should test. Prepare a set of test items, problems or a brief practice exercise requiring responses relevant to the objectives, in relation to the presentation format and content. Prepare a detailed scoring key for each posttest·and develop a set of procedural guides for adding each of these items to the management system. Decide how the posttests are to be scored, how immediate feedback is to be provided to the student, and how the data are to be collected for revision purposes. Each of these instructional components, like all others, will have to be evaluated in terms of effectiveness, and later revisions will be made.

Some of the presentations, although appearing appropriate for the posttest method, might have to be converted to the sequential response requirement format if the data indicate that the posttest method is not working satisfactorily. Develop the instructions for the student, telling him how to use the materials, and any other information that he might need, including perhaps, directions for loading, operating, and unloading projectors or tape units. Add descriptions of these materials to the list of required or optional resources.

6. Work on the category two materials next. Each of these also needs a posttest or practice exercise. Prepare these as you did in the preceding step, using the objectives and criterion items for reference. Now, referring to that posttest or practice exercise and to the content, develop a sequence of questions, problems, or tasks to be inserted at appropriate points in the presentation sequence. These should be relatively brief, requiring brief responses to avoid disrupting the flow of the presentation. Do not set any predetermined number of responses--such as 10 responses per 20 minute presentation--since our purpose here is *relevant* responding, not responding for its own sake. A relevant reference here, one referred to in another portion of this Supplement is Susan Markle's *Good Frames and Bad*, which discusses the identification of relevant responses, as well as prompting and response specifications.

   These materials should be tested with students prior to field use in the on-going test version of the course. Develop the procedures for stopping the presentation and prepare the objectives, outlines, response worksheets, and posttests. Test the presentations, analyze the data as described earlier, and revise to eliminate deficiencies and administrative problems. Scoring keys and procedures for scoring and providing immediate feedback for the students will be necessary. Review the procedures described in the preceding step to be sure that all other supporting materials have been prepared and incorporated.

7. The borderline materials, category three, should first be developed as category one materials and tested on students. If that does not appear to do the job, and if revisions are not effective, then the difficulty level is too high for the posttest method, or other problems exist that require the category two approach. Follow all procedures for category one materials first, test the materials, and carry out all related tasks; reassign the materials to category two if necessary, and then carry out all category two tasks.

8. Review all materials and all supporting documentation, management procedures, etc. Revise or supplement if necessary, make all necessary changes to the lists of resources.

9. One minor experimental procedure might be considered here. During the first course implementation that involves more than, say, thirty students, assign the audiovisual materials as required materials to about ten students, optional for ten others, and not available to the others. No complex statistical design is required here, since we are only looking for evidence of effectiveness of the materials. The data need to be arrayed in the kind of matrix described in the model, and examined to see if there is any evidence that the materials contribute to attainment of the objectives.

   Both unit posttest and final criterion test data should be examined. If students appear to achieve the objectives as well without the audiovisual presentations as do students who used the materials, these materials should probably be made optional. If students did better when they used the audiovisual material, then the materials might be required of all students. When poorer students, those requiring the most time and the most remedial assistance, appear to profit from the audiovisual materials even though the better students do not, then a method of prescribing the materials to the weaker students might well be appropriate.

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# 5

# COMPLEXITY OF LEARNING OBJECTIVES: A CLASSIFICATION HIERARCHY

*Introduces and evaluates an objective classification hierarchy based on the complexity of hard science objectives. This classification method is important to course development and management because it is highly predictive of student performance.*

# COMPLEXITY OF LEARNING OBJECTIVES

## Table of Contents

I. INTRODUCTION. . . . . . . . . . . . . . . . . . . . 1

II. DEFINING LEARNING OBJECTIVES. . . . . . . . . . 2

III. CLASSIFYING LEARNING OBJECTIVES . . . . . . . 6

IV. THE HIERARCHY DEFINED . . . . . . . . . . . . . 9

V. THE EXPERIMENT. . . . . . . . . . . . . . . . . .11

VI. CALCULATIONS AND RESULTS. . . . . . . . . . . .12

VII. DISCUSSION. . . . . . . . . . . . . . . . . . . . .16

# COMPLEXITY OF LEARNING OBJECTIVES

## Table of Figures

FIGURE 1 ....................................13

FIGURE 2 ....................................15

FIGURE 3 ....................................15

FIGURE 4 ....................................16

# COMPLEXITY OF LEARNING OBJECTIVES: A CLASSIFICATION HIERARCHY

## I. INTRODUCTION

Writing learning objectives for highly quantitative hard science courses requires careful specification of an elusive measure of level. For example, high school and college physics courses may cover essentially the same topical material, but with a profound difference in requirements and expected performance. One objective of this study was to develop a taxonomy which would categorize high level physics problem-solving behaviors, and to examine the usefulness of such a classification system.

The classification of learning objectives utilized is based on complexity, a nonarbitrary measure which does not rely upon comparison between students. Basically, the scheme is to count the number of computational steps required. We examine the consistency between the proposed classification of complexity and the more familiar measure of student difficulty. By using the system to determine the significance of complexity as a variable in absolute and relative student performance, the relationships between student performance and levels of complexity can be investigated.

The classification system, as presented in this section, evolved as a pragmatic consequence of an attempt to categorize the objectives of a physics program developed by educators for the U. S. Naval Academy. Originally, the objectives were defined by verbal descriptions of the intended behavior, but various difficulties indicated a need to present objectives in more precise terms, as discussed in Section II of this chapter. Objectives were therefore translated into problem form. The effort required for classifying was thus reduced to one of categorizing physics problems.

Once the objectives were defined in problem form, a classification scheme had to be developed. An objective measure of problem complexity, the number of computational steps required to solve the problem, was adopted. "A taxonomy must be validated by demonstrating its consistency with the theoretical views in research findings of the field it attempts to order."[1] (A general discussion of taxonomies is presented in Section III of this chapter.)

The classification scheme proposed in Section IV fits the definition of taxonomy, as determined empirically. This procedure of counting mathematical steps is objective and a majority of physics questions fall uniquely and unambiguously into one of three categories. These categories have a clear hierarchal structure and can be assigned a numerical measure so that complexity can be viewed as an independent variable in student performance.

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[1] Benjamin S. Bloom, J. Thomas Hastings, and George F. Madaus, *Handbook on Formative and Summative Evaluation of Student Learning*, (New York, 1971), p. 17.

The classification system was tested at the Naval Academy. The subjects in the experiment were sophomore midshipmen, well above average in verbal and mathematical skill. Section V describes the experiment.

The results and conclusions are discussed in Section VI, and implications are drawn in Section VII.

## II: DEFINING LEARNING OBJECTIVES

The need for defining objectives cannot be overemphasized. Leonard Blackman, in *Frontiers in Education*, feels: "The development of education as a science rather than an art form will be wholly dependent on concrete and measurable statements of educational objectives coupled with the highly specific delineation of instructional procedures leading toward those objectives."[2] Creating and constructing a detailed and comprehensive set of behavioral objectives is, then, a first major step in the process of course development. The objectives, taken collectively, define the content, scope, and organization of the course. They specify for both the student and the teacher the content and processes to be learned, and indicate the intended behavior of the student upon completion of the course.

In addition to defining the course, the objectives provide the course instructor or designer with a basis for evaluating student performance and course materials, and a basis from which revision processes can be derived. In a recent handbook by Benjamin Bloom, Leopold Klopfer promoted another use for objectives.

> In numerous science evaluation situations when observations of a student's performance are called for, there is a substantial degree of uncertainty in deciding how well he has done and how to guide him to do better...The problem, then, is to find ways of developing much more detailed and precise specifications than have heretofore been attempted of the behaviors that the student is to attain. These specifications would also delineate the prerequisite behaviors leading to the desired criterion behaviors, so that the student who has not attained mastery may be given soundly based guidance.[3]

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[2] Blackman, Leonard S., "The 'Brave New World' of Special Education," *Frontiers in Education*, ed. Morey R. Fields (New York 1967), p. 17.

[3] "Evaluation of Learning in Science," *Handbook on Formative and Summative Evaluation of Student Learning*, Benjamin S. Bloom, et. al. (New York, 1971), pp. 637-638.

Because the objectives "identify the kind of behavior that will be accepted as evidence that the learner has achieved them,"[4] one can determine exactly how much of what was taught was actually learned. Data obtained by analysis of test items related to the objectives are able to provide system users with information as to which objectives have not been successfully attained.

Still more can be provided by well-defined objectives. They perform an important organizational task for the student. As "advance organizers," they provide a label under which the learner can store new knowledge and concepts. Too, they can work as synthesizing agents, relating separate items to form a larger whole. "The usefulness of a structure for learning has to do with the ability of students...to use it as an organizing factor in their learning."[5]

Much of Robert Mager's work has attempted to impress the educational community with the need to define objectives specifically. A meaningful objective is one that communicates to the reader the writer's instructional intent; the best statement is one that excludes the greatest number of possible alternatives, which succeeds in describing the terminal behavior of the learner well enough to preclude misinterpretation. Others agree with Mager's requirement that the objectives be specific.

> A statement of an objective is an attempt by the teacher or curriculum maker to clarify within his own mind or communicate to others the sought-for changes in the learner. To accomplish this, the educator must choose words that convey the same meaning to all intended readers. Statements of objectives that can be interpreted differently by different readers give them no direction in selecting materials, organizing content, and describing obtained outcomes, nor do they provide a common basis for instruction or evaluation.[6]

The definition of an objective should include three aspects. First, it must specify the behavior that must be elicited from the learner, preferably in terms that are understandable to both the instructor and the learner. Because we cannot see learning directly, we must base our analysis of learning on something more evident. "The change in performance is what leads to the conclusion that learning has occurred."[7]

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[4] Barabara E. Schure, "The Computer: An Adaptive Teacher," *Some Essays on Computers in Education*, ed. Margaret E. Pincus (Cambridge, Mass., Spring 1967), p. 51.

[5] Bloom, *Handbook*, p. 12.

[6] Bloom, *Handbook*, p. 20.

[7] Robert M. Gagne, *The Conditions of Learning*, (New York, 1965), p. 6.

> The short-term objectives must be stated in an unambiguous way so that they are clear, not only to the teacher himself...In order to communicate objectives precisely and unambiguously, it is not enough to specify independently the content to be covered or the abilities and skills the student is expected to acquire. Communicability requires accurate statements of the expected behavioral changes related to a particular content area.[8]

Second, the conditions under which this learning is to be demonstrated should be specified. If textbooks, slide rules, and other information sources can be consulted, the objective should so state. If the objective is to be achieved within a time limit, or if any other operating constraints are imposed, these should also be specified.

The criteria of acceptable performance is another aspect which should be included in the process of defining objectives. The student and instructor must both know what degree of competence is required and what measurable evidence of this achievement will be acceptable.

> One way of making the objectives more detailed is to specify the behaviors the student should possess or exhibit if he has attained the objectives...Another way of giving further clarity to the specifications of outcomes is to represent them in the form of the problems, questions, tasks, and the like which the student should be able to do or the kinds of reactions he should give to specific questions or situations.[9]

By developing criterion test items to clarify acceptable behavior at the time the objectives are defined, a basis for measuring the achievement of an objective becomes available, and, at the same time, the possibility of making the objectives depend on relative performance is avoided. Measurement of achievement, Branson emphasizes, must be on an absolute standard, "since each person in the class has the opportunity to meet the prescribed specifications, regardless of how well or poorly his classmates do."[10] Relative achievement of one student against another defers establishment of levels of acceptable competence until student papers are graded.

Thus, the term "Measurable Behavioral Ojective (MBO) is built. Since not all objectives are equivalent in importance, scope, or complexity, these MBOs can be grouped into terminal and enabling objectives. Terminal objectives are the desired final behaviors and enabling objectives are the more specific smaller blocks leading toward the terminal objectives.

[8] Bloom, *Handbook*, p. 23.

[9] Bloom, *Handbook*, p. 15.

[10] Robert K. Branson, "The Criterion Problem in Programmed Instruction," *Educational Technology*, July 1970, p. 36.

Enabling objectives represent the transitional type of skill or knowledge which is believed to be a precondition for success on the terminal objective. Not all the enabling objectives are of equal importance, nor do we assume that they are of equal degree of difficulty to attain. Enabling objectives may or may not "build" upon each other; it is sufficient only that they facilitate the mastery of their associated terminal objectives. There are, then, distinct simpler behaviors as components of more complex behaviors.[11]

Intuition suggests that not all learning is the same, and observation and research concur. "A serious attempt to describe learning must take all these varieties into account. Naturally, it must make differentiations among them, and classifications of them, if these are possible."[12] What we attempt to do with defined objectives, then, is "to order phenomena in ways which will reveal some of their essential properties as well as the interrelationships among them."[13]

The physics project was begun with verbal statements of objectives. Their lack of precision, however, resulted in a lack of clarity. Students were not able to assess the objective's level and scope, and so were not certain exactly what was expected of them. Professors with little specific classroom experience, regardless of their subject matter expertise, could not be sure to what extent any content was to be covered. Although there was professorial consensus on a list of objectives, there was little agreement on whether the objectives were achieved; evaluation of student progress was less than standardized.

Use of verbal objectives revealed another more serious, though less obvious, hazard. Enabling objectives are clearly discerned by the course instructor or designer only when the student executes the behavior called for in the terminal objective. Each necessary step toward terminal behavior is then, by definition, an enabling objective. When a terminal objective is "fuzzy," the requisite steps for its achievement are even less clear. Our experience has been that this situation leads to poor ordering of enabling objectives under a terminal objective, a number of redundant enabling objectives, and a few omissions of enabling objectives.

The objectives were reformulated into problem form to eliminate these difficulties. With a precise problem to represent a terminal objective, any subject matter expert can perform the steps for its solution and identify the individual steps as enabling objectives. Moreover, specifying objectives in problem form indicates to students what behavior will be considered acceptable and under what constraints their behavior must be evidenced.

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[11] Benjamin S. Bloom, et al., *Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: The Cognitive Domain* (New York, 1956), p. 16.

[12] Gagne, *Conditions*, p. 20.

[13] Bloom, *Taxonomy*, p. 17.

When acceptable performance is defined as correctly solving a problem, relative performance measures are obviated. Relative grades depend not on success in achieving the objectives, but on achieving more or fewer than other students.

> We have become accustomed to classifying students in about five levels of performance and assigning grades in some relative fashion. It matters not that the failures of one year performed at about the same level as the C students of another year. Nor does it matter that the A students of one school do about as well as the F students of another... There is nothing sacred about the normal curve. It is the distribution most appropriate to chance and random activity. Education is a purposeful activity, and we seek to have the students learn what we have to teach. If we are effective in our instruction, the distribution of achievement should be very different from the normal curve. In fact, we may even insist that our educational efforts have been *unsuccessful* to the extent that the distribution of achievement approximates the normal distribution.[14]

The concept of casting objectives into problem form follows closely from developing test questions with which to measure achievement of those objectives.

> As objectives are developed and approved by the subject matter expert, test questions will be developed to cover these objectives...In this way, one can determine from test items missed which educational objectives are not being met.[15]

By making the test items synonymous with the objectives, we have an indication of attainment of the objectives which is more closely related to the objective. "This represents the most detailed and precise definition...since it indicates the tasks the student is expected to perform and the specific behavior he is expected to exhibit."[16]

## III: CLASSIFYING LEARNING OBJECTIVES

There is no definitive system for classifying learning behaviors in a way which is suitable to all fields and levels of learning. Nor do the experts--educators, researchers, subject matter specialists--suggest that an ultimate model is necessary. Instead, in an attempt to classify learning conditions, general guidelines have been advanced which can be altered to suit specific courses of study.

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[14] Bloom, *Handbook*, p. 45

[15] Donald T. Tosti, *Research and Evaluation Plans, Part I*, (Westinghouse Learning Corporation, Palo Alto, Calif., January 1969), p. 12.

[16] Bloom, *Taxonomy*, pp. 44-45.

Generally accepted is the notion that we store information in a hierarchal manner, building upon simple facts and skills to develop more complex principles and concepts. Classification of behaviors into terminal and enabling forms implies a recognition that some behaviors are subordinate to others.

> The clearest evidence that problem solving 'can be conceived as a linear sequence of operations' is provided by the extensive work on simulation of cognitive processes...This same work also provides clear evidence of the importance of hierarchal relations, not only in problem solving but in other kinds of behavior.[17]

From that point of concurrence, independently developed taxonomies often vary, some based on difficulty, some on levels of abstractness, others on still other variables. This is no handicap, however, for there seems to be no reason to impose rigorous laws on the nature of learning. Rather, the ultimate purpose of any classification system is the need for more information about the learner and the task to be learned, and the relationship between these. As long as a taxonomy offers some insight to this end, it is a useful classification scheme.

Benjamin Bloom finds that "there could be an almost infinite number of ways of dividing and naming the domains of education outcomes,"[18] since the determination of classes is in some ways arbitrary. He suggests a hierarchy of levels of behavior that relate to the difficulty and complexity of the learning process.[19] Bloom and his associates divided the cognitive domain into six major classes of educational objectives, each in turn subdivided into further specific behavior classifications. The subdivisions of these major categories are vaguely defined, some being distinct in content rather than in form. Only by studying the example test items offered can some of the ambiguity be cleared away.

> Although we have little difficulty in determining the major class within which a behavior falls, we still are not satisfied that there are enough clearly defined subclassifications to provide adequately for the great variety of objectives we have attemped to classify.[20]

Bloom's intention of comprehensiveness, that is, setting up a classification scheme which would provide for all cognitive behavior found in an educational setting, demanded a certain degree of generality. The categories Bloom offers present a good generalized model of learning activities in the classroom. Because they are so inclusive, covering "a greater range of educational objectives than is typical at the secondary or college level,"[21] some alteration of the basic scheme is necessary in order to apply it to any specific field.

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[17] Donald W. Taylor, "Discussion of Papers by Adriaan D. de Groot and by Jeffery M. Paige and Herbert A. Simon," *Problem Solving: Research, Method, and Theory*, ed. Benjamin Kleinmuntz (New York, 1966), p. 124.

[18] Bloom, *Taxonomy*, p. 13.

[19] Bloom, *Handbook*, p. 119.

[20] Bloom, *Taxonomy*, p. 21.

One can be more specific about categorizing objectives by narrowing the variety under investigation. "It is evident that the use of a limited number of categories, or components of knowledge or skill, does not necessarily imply a limited number of kinds of knowledge or skill."[22] What is gained by focusing our attention more specifically on the higher level problem-solving categories is a classification system appropriate for ordering physics problem complexity.

Complexity, to distinguish it from difficulty, is a nonarbitrary objective standard. It is a quality inherent in the task. Depending upon one's qualifications, it may be easy or difficult to achieve. In either case, complexity level can be determined in the absence of performance measures and does not require knowledge of preceding learning experience.

Difficulty, on the other hand, is a more relative and more subjective measure. It is often determined by professorial experience with prior student performance on similar terms, or by analysis of student performance, often long after it would be useful for formative evaluation. When Bloom says that a reader "must know...the learning situations which have preceded the test,"[23] we are reminded that he does not clearly distinguish between difficulty and complexity (see n. 19, above). Expected high correlation is between these two measures, but their equivalence cannot be assumed.

By comparing problem complexity with student difficulty, evidence should be found of the appropriateness of our hierarchy. "If this is the real order from simple to complex, it should be related to an order of difficulty such that problems requiring behavior A alone should be answered correctly more frequently than problems requiring AB."[24] It is believed that difficulty, too, follows a hierarchal order:

> That is, the test items for knowledge of specific facts or terms should be passed by more students than those for

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[21] Bloom, *Taxonomy*, p. 25

[22] Francis Mechner, "Behavioral Analysis and Instructional Sequencing," *Programmed Instruction*, ed. Phil C. Lange (Chicago, 1967), p. 83.

[23] Bloom, *Taxonomy*, p. 51.

[24] Bloom, *Taxonomy*, p. 23.

> knowledge of rules and principles or skill in the use of processes. Also, the test items involving translation and application are likely to be more difficult, and thus to be passed by fewer students.[25]

If correlations between these two measures are high, it would suggest a validity in our taxonomy.

## IV: THE HIERARCHY DEFINED

Earlier classification systems advanced were inappropriate for one or more reasons: too general, covering more kinds of behavior than were apparent or necessary to test in a physics problem-solving course; too ambiguously or nonobjectively defined, requiring suppositions about internal thought processes or arbitrary assignment to subclassifications; too history dependent, requiring previous learning experiences as a base. For these reasons, it was decided to adopt an objective measure of problem complexity for categorization purposes. This was taken to be the number of computational steps required to solve the problem in question; in short, a measure of complexity determined by counting mathematical steps.

For this initial investigation, three categories of objectives were identified, and a catch-all gray category was invented. They are listed in order of increasing complexity:

1. Zero Step Problems: Those questions which do not require any mathematical manipulation. Recall of a fact or definition, or the recognition of an object, fact, or definition fall into this category. Even difficult conceptual problems or associations are categorized as zero step questions whenever there are no algebraic steps involved. All word problems; that is, problems which are nonnumerical and nonsymbolic, are zero step problems.

2. One Step Problems: Those problems which require the solution of one algebraic equation for one unknown, or a single calculus operation (differentiation or integration).

3. Multiple Step Problems: All problems which require the solution of *more than* one algebraic equation, or more than one calculus operation.

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[25] Bloom, *Handbook*, p. 129.

New York Institute of Technology researchers did not distinguish between two, three, or more step problems, since they found they could analyze the number of steps only in the intended behavior, not the actual behavior. "We do not expect all students to use the skills acquired in a course in exactly the same way. The higher one proceeds up the education ladder, the more apparent this becomes." By eliminating the distinction between, say, two and three step problems, the difference between intended and actual behavior was minimized.

In addition, when more than a single operation (step) is required to solve a problem, even experts frequently disagree as to the "best" way to solve it and the number of steps required.

> Many problems give no clue as to how many, or what, intermediate steps must be taken...And if the operation is not a formal analytic tool, like arithmetic addition, two solvers may apply the same operation with different numbers of steps.

Clearly, ambiguities in the step counting process are much more likely to occur in multiple step problems.

A fourth catch-all category included all problems which were judged not valid or which did not fall precisely into one of the three categories. Problems which had errors, insufficient information, or ambiguities were relegated to this category, as were many graphical problems which require geometrical steps rather than algebraic steps.

A majority of problems lacking clear definition required simple arithmetic operations; the investigators did not want to equate trivial arithmetic computations with algebraic steps.

Of course, all the valid problems can still be assigned to categories by making the above definitions more exhaustive and detailed. More inclusive categories will be developed in the future; during the research, it was desired to examine the most elemental scheme without including all possible ramifications.

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[26] Bloom, *Handbook*, p. 26.

[27] Helen I. Snyder. *Contemporary Educational Psychology: Some Models Applied to the School Setting* (New York, 1968, p.66.

## V. THE EXPERIMENT

The course materials and procedures discussed below describe, in part, the physics course delivered under Contract No. N00600-68C-0749 to the U. S. Office of Education for development, validation, and installation at the U. S. Naval Academy. The course, as delivered, is self-paced, independent study, multimedia, computer or manually managed, introductory classical physics.

There were 513 students available for taking the required course at the Academy in the Fall 1969 semester. All had finished one year of college at the Academy and were generally engineering and applied science majors. Their college experience included one year of chemistry and introductory calculus. Understandably, this was a highly select and homogeneous group of subjects. The students were randomly assigned to one of three groups. Control Group I consisted of students taking the conventional course, as it had been developed and taught by the Academy Physics staff. Control Group II consisted of students also taking the conventional course, but, in addition, being given the criterion tests developed for the multimedia course.

The Experimental Group was made up of those students taking the multimedia course developed by N.Y.I.T. under contract to the Office of Education. Each week, the students were required to complete a Study Guide in the form of a scrambled text, which consisted of 45 to 72 problems. The students responded to these multiple choice problems on IBM punch cards, which served as recording and directing devices, since the student had to punch his card to find out where to go for the next question and to find out if he had made the correct answer selection. As he progressed through the Study Guide, he was directed to media presentations, readings, homework assignments, and the various other course components. The students worked at their own rates throughout the week, but were required to take the criterion test together at the end of each week.

Each student was given a copy of the test, and wrote his answers on separate answer forms, which were then scored by comparing responses to those listed on a pre-established answer key. In order to encourage the students to work consistently throughout the semester, it was recommended that the criterion tests be weighted as 60% of the total grade.

Criterion test questions were prepared from the verbal objectives of the development phase of the project by the same team of physicists who developed the course materials. The test questions were then sent to Annapolis for approval by those members of the Navy Physics staff who were involved in the multimedia project. The approved problems, with any alterations, additions, or deletions, were then returned to the project team at N.Y.I.T., where the questions were analyzed and assigned to one of three problem categories: zero step, one step, and multiple step. Those problems which could not be uniquely classified into one of these categories were assigned to a fourth category, gray. Later, if errors which would affect performance were found in a problem, it too was reclassified as gray, and excluded from the analyses.

The criterion test for the week's work was given on Saturday morning to the midshipmen at the Academy who participated in the multimedia course. Tests varied in length from seven to ten problems, most having ten. A total of 79 of the 126 problems were acceptably classified in this initial effort.

Those students absent from a group session when the weekly tests were given had the opportunity for a make-up exam at a later date. Because the exact nature of the make-up test could not be controlled at N.Y.I.T., only those students having taken all 79 criterion test questions used for analysis were included in the present study. Of 197 students in the Experimental Group, only 41 students fulfilled this requirement.

Analyses were conducted on the set of 41 subjects who had complete data on all criterion test questions determined to be nonarbitrary. The problems were sorted by learning category, and percentage correct in each category was computed for each student.

## VI: CALCULATIONS AND RESULTS

Analysis of the gathered data is directed toward three interrelated questions:

1. Is categorizing by complexity consistent with more familiar measures of performance?

2. What is the relationship between complexity and absolute student performance; is complexity a good predictive variable?

3. What is the relationship between complexity and relative student performance; is complexity a good predictive variable?

Intuition dictates that problem solving difficulty should be well correlated with any reasonable measure of problem complexity. As an objective standard of student performance difficulty, the percentage incorrect for each student in each category is taken. By assigning numerical measures to the complexity categories; 0, 1, and 2 to zero step, one step, and multiple step, respectively, the relationship between the categories of complexity and student difficulty is found. The correlation coefficient obtained is

$$r = .94$$

which is significant at the .01 level. Clearly, difficulty and complexity are well correlated, and we conclude that our measure of complexity is consistent with the more familiar measure of student difficulty. The special advantage, of course, of the complexity hierarchy is that it can be determined *before* testing takes place; whereas an objective measure of student difficulty can only be obtained after a performace check.

The data indicate that complexity as defined in this paper is an important variable for absolute student performance in problem solving. Remarkably, average percentage correct for all students in each category (71%, 61%, 49%), is virtually a perfect linear function of complexity, as illustrated in Figure 1. The decline of absolute performance with increasing complexity is completely expected.

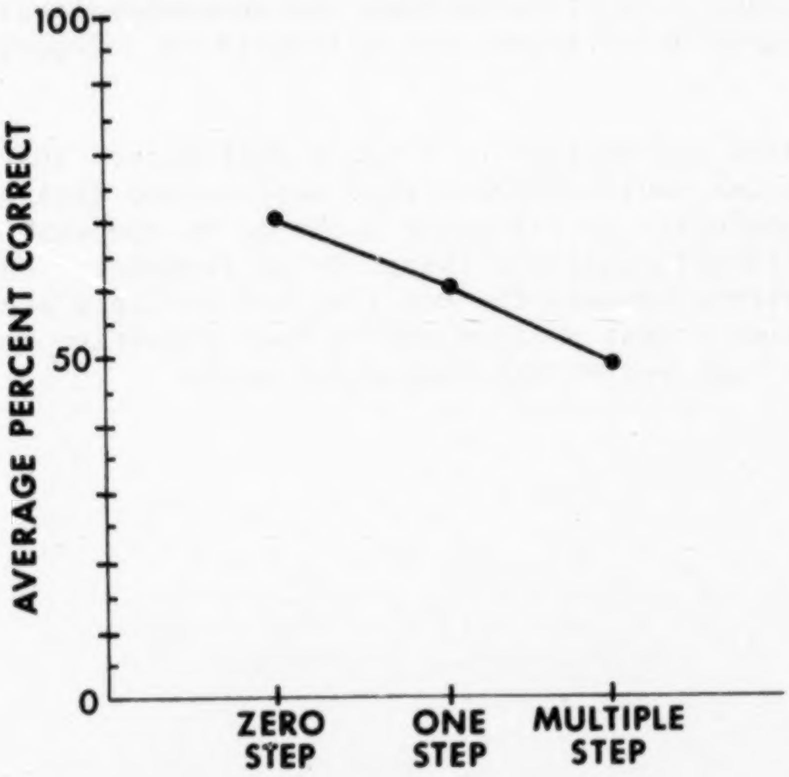

Figure 1
Average percentage correct for all students in each category.

Correlations of student performance scores for the three pairs of categories were calculated. (Figures 2, 3, and 4 represent these correlations graphically.)

Zero step/Multiple step $r = .35$

Zero step/One step $r = .44$

One Step/Multiple step $r = .65$

The first correlation is significant to the .05 level; the other correlations are significant to the .01 level.

These correlations show clearly that absolute performance in zero step problems is not an accurate predictor of performance in one or multiple step problems. Even the higher correlation between one and multiple step (.65) is insufficient to make a definitive prediction of performance in multiple step problems based upon performance in one step problems. This conclusion may have important consequences for the physics graduate record examinations which are generally limited to zero and one step problems. When it is important to measure high capabilities for synthesizing complex problem elements, multiple step performance must still be tested.

We note that the correlations indicate a closer relation between the two categories which require mathematical manipulation (.65) than between the nonmathematical zero step category and the one step mathematical category (.44).

A perfect correlation of student performance in any pair of categories would indicate that performance does not depend upon complexity at all since a change in complexity (change in category) causes no change in performance. The larger correlations between the one step and multiple step categories indicate that performance is less sensitive to changes at the high end of the complexity scale.

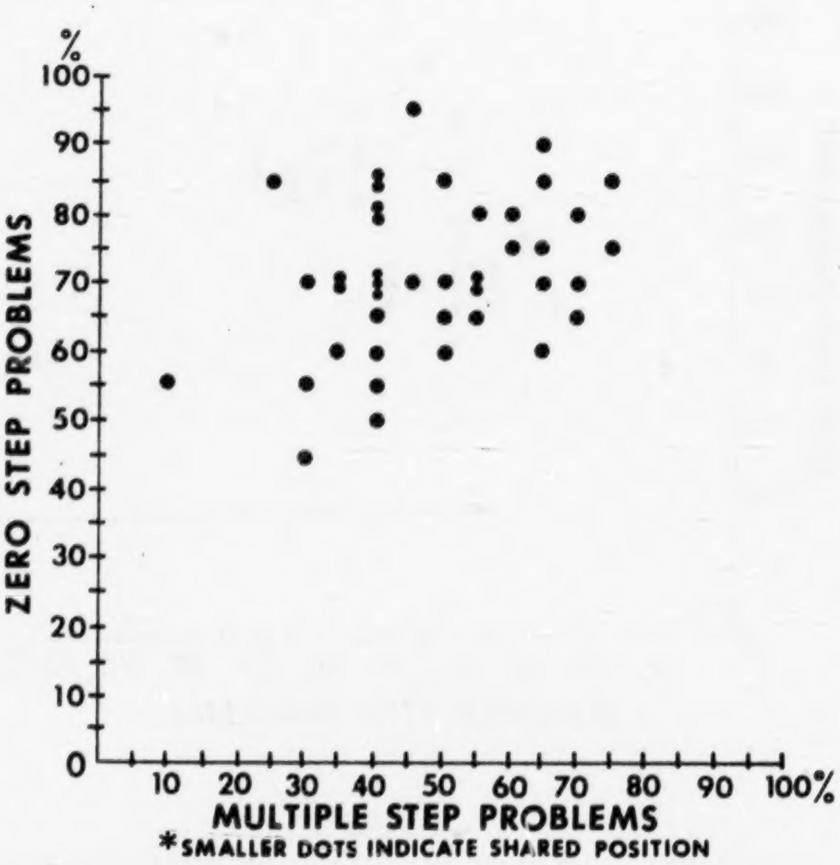

Figure 2 Correlation between zero step and multiple step problems.

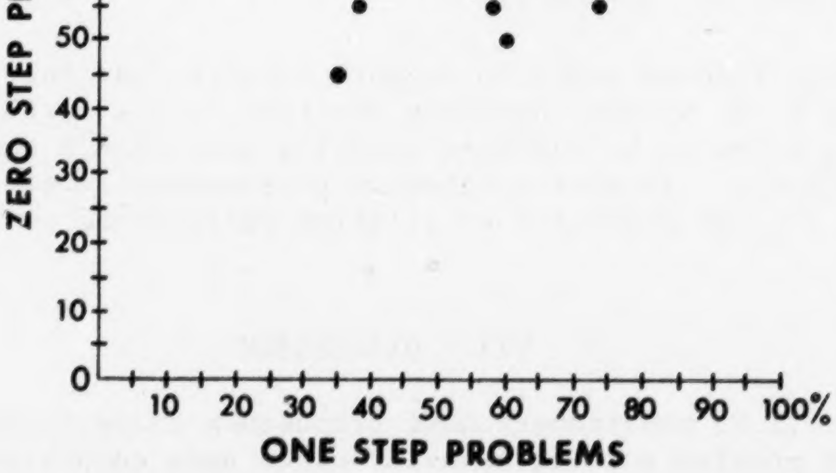

Figure 3 Correlation between zero step and one step problems.

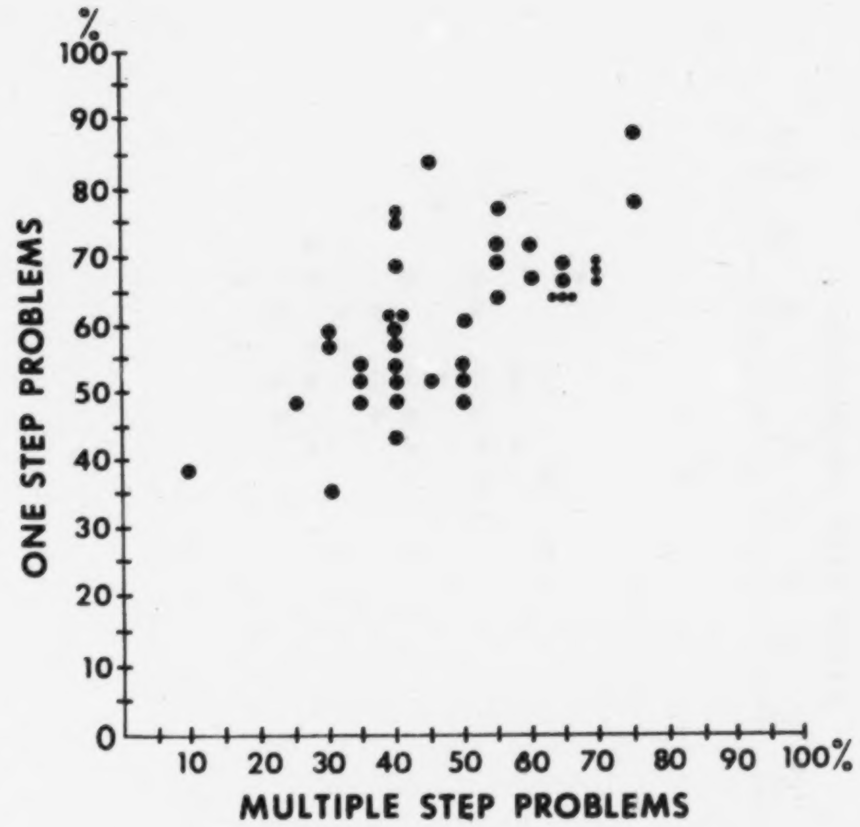

Figure 4
Correlation between one step and multiple step problems.

To ascertain whether relative performance in one category is related to relative performance in other categories, the Kendall W. was computed. This is a measure of concordance of student rank across all three categories. The result is

$$W = .63$$

which is significant at the .01 level. This agreement between ranks is not unexpected. The high correlation indicates that students roughly maintain their relative problem solving ability across all categories.

This finding tends to support the attitude that "a 'B' student is a 'B' student whatever the test." The correlation is still too low to be taken as anything more than a very rough indicator. In short, relative performance in two categories is a crude predictor of relative performance in a third category.

## VII: DISCUSSION

N.Y.I.T. researchers have proposed a classification system for problem solving behavior based upon complexity. The basic method was to classify according to the objective measure of computational steps required for the solution of the problem.

When the categories were assigned a numerical value, complexity was regarded as a mathematical variable upon which performance was strongly dependent. An increase in complexity resulted in a decrease in absolute performance. The analysis indicated a closer correlation between one and multiple step performance than between zero and one or zero and multiple performance. Analysis of concordance of rank indicated that students roughly maintain their ranks across complexity categories.

The finding of less sensitivity at the complex end of the hierarchy further justifies the lack of distinction between different numbers of multiple step problems. Originally, the investigators did not distinguish between levels of computational problems above two steps for a practical reason: determining how economical a student is in solving a multiple step problem is somewhat arbitrary. Experimental results are consistent with our categorizing these problems merely as multiple step.

Clearly, a prediction of student performance based solely on complexity would be questionable, but its utility as an index of problem difficulty cannot be minimized. Since a measurable objective must specify performance, and performance is highly dependent upon complexity, it follows that complexity should be specified for hard science objectives. Even if objectives are stated in problem form, the complexity category of the problem should be known in order that variations of the problem (for use on a final exam, or for comparison purposes) can have equivalent complexity.

> We are finally, slowly, painfully beginning to find better ways of measuring educational results, not just in terms of achievement in broad areas as measured by standardized tests and compared with group norms, but in terms of learning outcomes compared with objectives stated in behavioral terms.

The taxonomy advanced by this paper should prove to be a useful systematizing agent. Defining classes of behavior suggests certain implications for the establishment of those behaviors which guide our instructional procedures. As a result of this investigation, we would conclude that enabling objectives should not be more complex than the related terminal

[28] Robert W. Locke, "Has the Education Industry Lost Its Nerve? *Saturday Review*, January 16, 1971, p. 44

[29] Robert Gagne, "The Analysis of Instructional Objectives for the Design of Instruction." *Teaching Machines and Programmed Learning, II; Data and Directions*, ed. Robert Glaser (Washington, D. C., 1965), p. 25

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objective. Enabling objectives should facilitate success on the terminal objective; as the complexity of an enabling objective increases, it is likely to produce a decrease in performance.

The classification system investigated here presents a useful method of categorizing problem solving behavior. It is hoped that classification by complexity will contribute somewhat to our understanding of the educational process.

> A more adequate analysis and classification of the variety of the processes employed in thinking is prerequisite to the development of a more adequate theory of problem solving, or of thinking more generally. At this stage, it may well be most fruitful to focus upon the development of limited theories of problem solving...One would hope, however, that in the identification of processes in these limited areas, one might proceed to the construction of more general theories.

Taylor, p. 125.

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# 6

# INDIVIDUALIZED INSTRUCTION AND THE MANAGEMENT SYSTEM

*An investigation of the effectiveness of the Adaptive Instructional Management System to individualize instruction.*

# INDIVIDUALIZED INSTRUCTION
# AND
# THE MANAGEMENT SYSTEM

## Table of Contents

INTRODUCTION .................................... 1

CHARACTERISTICS ................................. 1

CONCLUSION ...................................... 13

## INDIVIDUALIZED INSTRUCTION AND THE MANAGEMENT SYSTEM

The research described in this document includes an investigation of the effectiveness of a computer-based management system which was designed to improve learning through the individualization of instruction. It became necessary, therefore, to verify as individualized instruction the strategies utilized by the management system to direct a student through the instructional materials of the data processing course. This chapter provides a summary of evidence towards such a verification.

In order to identify the requisite components of a program of individualized instruction, the investigator assigned to this task, Dr. Barbara Weinschel, conducted a thorough examination of articles and books written by educators concerned with the question of how to individualize instruction. Specifically, she examined books and articles written by:

1. Individuals who created, directed or conducted research on a computer-based teaching or management system designed to individualize instruction; or

2. Individuals who hold or held positions in high schools or colleges as researchers with a non-computer-based system designed to individualize instruction; or

3. Individuals whose works were referenced in scholarly bibliographies dealing with computer-assisted or computer-managed instruction or with the individualization of instruction; or

4. Educators who hold or held positions as full-time instructors in high schools or colleges and who published current (printed after 1958) textbooks on the methodology of instruction.

The examination of sources which met at least one of the criteria defined above permitted the researcher to identify fourteen characteristics, each of which is widely held to be an attribute of a program designed to individualize instruction. Each of these characteristics is now described and discussed in terms of its inclusion in or exclusion from the computer management system utilized in an attempt to individualize instruction in this study.

1. A wide variety of individualized core experiences involving a wide variety of instructional media are designed and included to teach each set of instructional objectives.

Virtually every source examined stressed the need for the design and inclusion in a program of individualized instruction of a variety of curriculum materials involving more than one medium to teach each set of learning objectives in the course. Cenci and Weaver,[1] Green, Koppes and Gassman,[2] Joyce,[3] Stolurow[4] and Wiles,[5] in books or articles which deal with teaching methodologies, emphasize that differing instructional materials utilizing differing communications media are necessary if the pupil is to progress through a program specially suited to his needs, abilities and rates of learning. Similarly, Bolvin,[6] Leese, Frasure and Johnson[7] and Ullmer,[8] in writings dealing with the design of curriculum materials for programs of individualized instruction, stress the need for a variety of instructional materials to teach each set of learning objectives. In articles and books dealing with individualized instruction, the Aerospace Education Foundation,[9] Blake and McPherson,[10]

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[1] Louis Cenci and Gilbert Weaver, Teaching Occupational Skills (New York: Pitman Publishing Corporation, 1968), p. 39.

[2] Alan Green, Wayne Koppes and M. C. Gassman, Educational Facilities with New Media (New York: Rensselaer Polytechnic Institute, 1965), p. 22.

[3] Bruce R. Joyce, "The Development of Teaching Strategies," Audiovisual Instruction, 13 (October, 1968), 821.

[4] Lawrence Stolurow, "Model the Master Teacher or Master the Teaching Model," Learning and the Educational Process, ed. John Krumboltz (Chicago: Rand McNally & Company, 1965), p. 239.

[5] Kimball Wiles, Teaching for Better Schools (New York: Prentice Hall, Inc., 1959), p. 159.

[6] John Bolvin, "Implications of the Individualization of Instruction for Curriculum and Instructional Design," Audiovisual Instruction, 13 (March, 1968), 238.

[7] Joseph Leese, Kenneth Frasure and Mauritz Johnson, The Teacher In Curriculum Making (New York: Harper and Row Publishers, Inc., 1961), p. 207.

[8] Eldon Ullmer, "Instructional Development in Higher Education: Basic Premises of a Learner Centered Approach," Educational Technology (April, 1969), 16.

[9] Aerospace Education Foundation, Identification Card for Individualized Instruction (Washington, D.C.: Aerospace Education Foundation, 1968), p. 1.

[10] Howard Blake and Ann McPherson, "Individualized Instruction - Where Are We?," Educational Technology (December, 1969), 64.

Filep,[11] Hicken,[12] Jarolimek,[13] Kemp and Eastman,[14] Lanier,[15] McKeegan,[16] Parker and Russell[17] and Swenson[18] point out the need for more than one individualized activity which can be utilized to teach each specified set of learning objectives. Finally, Adams,[19] Atkinson and Hansen,[20] Brudner,[21] Bundy,[22]

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[11] R. T. Filep, "Individualized Instruction and the Computer: Potential for Mass Education," AV Communication Review, 15 (Spring, 1967), 102.

[12] James Hicken, "An Experimental Analysis of the Effects on Pupil Achievement of Using an Electronic Computer in Individualizing Instruction Through Unit Teaching" (unpublished Ed.D. thesis, State University of New York [illegible] Buffalo, 1965), pp. 15-72.

[13] John Jarolimek, "A Study of Current Practices of Individualizing Instruction in Minnesota Schools" (unpublished Ph.D. thesis, University of Minnesota, 1955), pp. 67-8, 172.

[14] Jerrold Kemp and Stewart Eastman, "Teaching the One and the Many at the Same Time," Educational Screen and Audiovisual Guide, 46 (November, 1967), 26.

[15] Vincent Lanier, "Individualized Instruction," Arts and Activities, 61 (March, 1967), 37.

[16] High McKeegan, "What Individualizing Instruction Means to the Curriculum Director," Audiovisual Instruction, 13 (March, 1968), 233.

[17] J. C. Parker and D. H. Russell, "Ways of Providing for Individual Differences," Educational Leadership, 11 (December, 1953), 168-173.

[18] Esther J. Swenson, "Teacher Preparation," Individualizing Instruction: Sixty-first Yearbook of the National Society for the Study of Education, Part I (Chicago: N.S.S.E., 1962), pp. 287-304.

[19] E. N. Adams, "Computer Assisted Instruction," Computers and Automation, 15 (March, 1966), 3.

[20] Richard Atkinson and Duncan Hansen, "Computer-Assisted Instruction in Initial Reading: The Stanford Project," Reading Research Quarterly, 2 (Fall, 1966), 7.

[21] Harvey Brudner, "Computer Managed Instruction," Science, 162 (November, 1968), 974.

[22] Robert Bundy, "Computer-Assisted Instruction: Now and for the Future," Audiovisual Instruction, 12 (April, 1967), 345.

Dick,[23] Rath,[24] Schurdak,[25] Stolurow[26] and Weisgerber[27] point out the need to include at least two parallel sets of instructional materials designed to teach each group of educational objectives in computer-assisted instruction or computer-managed instruction systems attempting to individualize instruction.

In this investigation, two parallel sets of primary (non-remedial) instructional materials, each utilizing different media, were designed and included to teach each set of educational objectives. Thus, this first characteristic of a program designed to individualize instruction is included in the computer-based management system of this study.

2. A detailed diagnosis is made of the initial state with which the learner comes into a particular instructional situation.

A second requisite of a program which attempts to individualize instruction is a detailed diagnosis of the characteristics which each student brings to the learning situation. Bolvin and Glaser,[28] Clymer and Kearney,[29] Costa,[30] Filep,[31] Hicken[32] and others[33,34,35,36,37] stress the need to include in programs of individualized instruction the identification of the entry behavior of students. Specifically, these authors point out the need to determine the students' level of knowledge or performance in the areas which relate to the subject matter to be learned and to determine their ability, aptitude and personality characteristics.[38]

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[23] Walter Dick, "The Development and Current Status of Computer-Based Instruction," American Education Research Journal, 2 (January, 1965), 45.

[24] G. J. Rath, "Computer Assisted Instruction," Educational Screen and Audiovisual Guide, 46 (June, 1967), 26-7.

[25] John Schurdak, "An Approach to the Use of Computers in the Instructional Process and an Evaluation" (IBM Research Report RC-1432, July, 1965), p. 2.

[26] Lawrence Stolurow, "SOCRATES: System for Organizing Content to Review and Teach Educational Subjects," Seventeenth Annual Industrial Engineering Institute Proceedings (1965), 22-3.

[27] Robert Weisgerber, "Individually Managed Learning: Project PLAN," Audiovisual Instruction, 13 (October, 1968), 836-7.

[28] John Bolvin and Robert Glaser, "Developmental Aspects of Individually Prescribed Instruction," Audiovisual Instruction, 13 (October, 1968), 829.

In this study, a testing battery consisting of a pretest, seven standardized examinations and a personal data form was administered prior to instruction so that the level of knowledge of data processing and various ability, aptitude and personality characteristics of each student in the data processing course would be assessed and input to the computer management system. Thus, the second characteristic of programs designed to individualize instruction is included in the management system of this investigation.

3. The characteristics of each student play a major role in the selection of objectives, the sequence of studies and the choice of materials and procedures.

In writings about programs of individualized instruction, the

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[29] Theodore Clymer and Nolan C. Kearney, "Curricular and Instructional Provisions for Individual Differences," Individualizing Instruction: Sixty-first Yearbook of the National Society for the Study of Education, Part I (Chicago: N.S.S.E., 1962), p. 276.

[30] Arthur Costa, "Strategies for Developing Autonomous Learners," Audiovisual Instruction, 13 (October, 1968), 833.

[31] Filep, *op. cit.*, pp. 103-4. [32] Hicken, *op. cit.*, p. 154.

[33] Jarolimek, *op. cit.*, pp. 62, 89, 172.

[34] Lanier, *op. cit.*, p. 345.

[35] Ralph Melaragno, "Two Methods for Adapting Self-Instructional Materials to Individual Differences," Journal of Educational Psychology, 58 (December, 1967), 238.

[36] Weisgerber, *op. cit.*, p. 837.

[37] Lawrence Stolurow, "SOCRATES: System for Organizing Content to Review and Teach Educational Subjects," Seventeenth Annual Industrial Engineering Institute Proceedings (1965), 23.

[38] *Ibid.*

Aerospace Education Foundation,[39] Bolvin and Glaser,[40] Clymer and Kearney,[41] Dean,[42] DeHaan and Doll,[43] Hicken,[44] Jarolimek,[45] McKeegan[46] and others[47,48,49,50,51] emphasize that once the entry behaviors of students are identified, these characteristics must play a major role in the choice and sequence of educational objectives, instructional materials and teaching strategies. Similarly, Adams,[52] Brudner,[53] Bundy,[54] Filep,[55] Rath,[56] Schurdak[57] and Stolurow,[58] in writings about computer-based systems which effect individualized instruction, stress the importance of utilizing the diagnosed characteristics of students in determining the instructional materials and methodologies prescribed to the individual student.

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[39] Aerospace Education Foundation, op. cit., p. 1.

[40] Bolvin and Glaser, op. cit., p. 829.

[41] Clymer and Kearney, op. cit., p. 277.

[42] Ray Dean, "Individualized Instruction in the Elementary and Secondary Schools of the United States, 1888-1940" (unpublished Ph.D. thesis, Leland Stanford Junior University, 1943), p. 101.

[43] Robert DeHaan and Ronald Doll, "Individualization and Human Potential," Individualizing Instruction: Sixty-first Yearbook of the National Society for the Study of Education, Part I (Chicago: N.S.S.E., 1962), p. 19.

[44] Hicken, op. cit., p. 44.

[45] Jarolimek, op. cit., pp. 67-68, 172.

[46] McKeegan, op. cit., pp. 233, 237.

[47] Parker and Russell, op. cit., 168-173.

[48] Harold Shane, "The School and Individual Differences," Individualizing Instruction: Sixty-first Yearbook of the National Society for the Study of Education, Part I (Chicago: N.S.S.E., 1962), p. 59.

[49] Richard Smallwood, A Decision Structure for Teaching Machines (Cambridge, Massachusetts: The M.I.T. Press, 1962), p. 7.

[50] Lanier, op. cit., p. 37.

[51] Melaragno, op. cit., p. 328.

[52] Adams, op. cit., p. 3.

[53] Brudner, op. cit., pp. 973-4.

[54] Bundy, op. cit., p. 345.

[55] Filep, op. cit., pp. 103-4.

[56] Rath, op. cit., pp. 26-7.

[57] Schurdak, op. cit., pp. 2-3.

[58] Lawrence Stolurow, "SOCRATES: System for Organizing Content to Review and Teach Educational Subjects," Seventeenth Annual Industrial Engineering Institute Proceedings (1965), pp. 22-26.

Since this investigation was concerned with an assessment of the ability of a computer-based management system to teach a defined and ordered set of objectives to all students in the study, the selection and sequence of objectives was fixed for all students. The choice by the management system of materials and instructional strategies - CAI or non-CAI, programmed or non-programmed learning was, however, based entirely on the entering and performance characteristics of each student. Thus, another major component of a program of individualized instruction is included in the management system of investigation.

4. Information is gathered and utilized which permits the prediction of the probable effectiveness of the differing instructional materials for individuals with differing patterns of entry behavior.

In articles which described in detail computer-based systems for the management of instruction, Stolurow,[59] Brudner[60] and Weisgerber,[61] stress the need for the inclusion, in such systems, of information which permits the prediction of the instructional materials best suited to teach specified objectives to students possessing given entry characteristics. In this investigation, the employment of the Wherry-Doolittle program with data on students in Group 1, permitted the prediction, prior to instruction, of the curriculum materials for each unit that would be best suited to teach specified learning objectives of that unit to each student in Group 2. Thus, the fourth component of a system designed to individualize instruction is included in the management system of this study.

5. Provisions are made for remedial and enrichment work.

Blake and McPherson,[62] Brudner,[63] Dean,[64] Filep,[65] Morrison and Adams[66] and others[67,68,69,70,71] point out that computer-based and non-computer-based programs for the individualization of instruction should provide opportunities for remedial and/or enrichment work. Since this investigation was concerned, in part, with the empirical identification of instructional materials best suited to teach specific objectives to students possessing given learning characteristics, the investigator restricted the addition of alternative (non-CAI) instructional materials to one set of such materials for each successive group. While this restriction limited the opportunity to explore a wide variety of instructional materials for enrichment or in-depth study, it was necessary for the systematic assessment of the effectiveness with given students of each set of instructional materials. Extensive provisions were made, however, for the prescription and study of remedial work. As indicated below, the performance of students in the course was continuously assessed, and pupils were referred automatically through daily progress reports to remedial work consisting of printed materials, tapes and films designed to alleviate diagnosed learning difficulties. In short, while of necessity the computer management system provided limited opportunity for enrichment work, it both provided extensive opportunities for remedial work and required that where prescribed, students study the remedial materials before progressing in the course.

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[59] Ibid., pp. 23-4.

[60] Brudner, op. cit., p. 974.

[61] Weisgerber, op. cit., pp. 835-9.

[62] Blake and McPherson, op. cit., p. 64.

[63] Brudner, op. cit., p. 974.

[64] Dean, op. cit., p. 101.

[65] Filep, op. cit., p. 103.

6. The performance of each student is monitored and continuously assessed and adaptation of his instruction is made continually on the basis of this assessment.

In articles describing computer-based and non-computer-based programs for the individualization of instruction, Stolurow,[72] Blake and McPherson,[73] Bolvin and Glaser,[74] Brudner,[75] Dean,[76] McKeegan,[77] Melaragno[78] and others[79,80,81,82] stress the need for continued assessment of the performance of each student and for the adaptation of the instructional materials and/or strategies employed with each student on the basis of this assessment. As indicated above, in this investigation, the performance of each student in the course was monitored and assessed daily. The progress of each student was evaluated and referrals to secondary instructional materials to be studied were made immediately when learning difficulties were diagnosed. Further, the instructional materials prescribed for a given unit varied according to the student's performance in prior units. Thus, instructional materials and strategies prescribed to the individual student were adapted as the student progressed through the course and his performance with given instructional materials was evaluated. The management system thus meets another condition of individualized instruction.

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[66] H. W. Morrison and E. N. Adams, "Pilot Study of a CAI Laboratory in German," The Modern Language Journal, 52 (May, 1968), 284-5.

[67] Parker and Russell, op. cit., pp. 168-173.

[68] Schurdak, op. cit., pp. 2-3.

[69] Patrick Suppes, "Computer-Based Instruction," Wisconsin Journal of Education, 100 (January, 1968), 11.

[70] Ullmer, op. cit., p. 16.

[71] Lawrence Stolurow, "SOCRATES: System for Organizing Content to Review and Teach Educational Subjects," Seventeenth Annual Industrial Engineering Institute Proceedings (1965), 23.

[72] Ibid., pp. 22-27.

7. Provision is made for the student to receive greater and faster feedback relating to his progress than is possible under group instruction.

Adams,[83] Brudner,[84] Dean,[85] Schurdak,[86] Weisgerber[87] and

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[73] Blake and McPherson, op. cit., p. 64.

[74] Bolvin and Glaser, op. cit., p. 831.

[75] Brudner, op. cit., p. 974.

[76] Dean, op. cit., p. 101.

[77] McKeegan, op. cit., p. 237.

[78] Melaragno, op. cit., p. 328.

[79] Morrison and Adams, op. cit., p. 285.

[80] Schurdak, op. cit., pp. 2-4.

[81] Suppes, op. cit., p. 11.

[82] Weisgerber, op. cit., pp. 836-7.

[83] Adams, op. cit., p. 3.

[84] Brudner, op. cit., p. 972.

[85] Dean, op. cit., p. 101.

[86] Schurdak, op. cit., pp. 2-3.

[87] Weisgerber, op. cit., p. 837.

Stolurow[88] identify still another characteristic of programs of individualized instruction--the provision of fast feedback in large quantities to the student on his progress in the course of instruction. In this investigation, students received immediate feedback on their responses to questions presented via the computer. In addition, each student received daily reports on his progress with the instructional material (CAI or non-CAI) studied during his previous learning session. Thus, the computer management system provided fast feedback in great quantities to each student in the data processing course.

> 8. Provision is made for the evaluation of the effectiveness of instructional materials in teaching given objectives to given students and for the adaptation of instruction on the basis of these evaluations.

Stolurow,[89] Bolvin,[90] Brudner,[91] Bundy,[92] McKeegan,[93] Smallwood[94] and Weisgerber[95] emphasize that systems designed to individualize instruction must involve a strong evaluation component. They stress the need for the collection of data which permit the evaluation of the effectiveness of given instructional materials in teaching specific objectives to students with specified learning characteristics. They further stress the need to incorporate the data obtained and the results of evaluations on these data into the system so that it is adaptive and self-improving.

In this investigation, provision was made both for the evaluation of the effectiveness of instructional materials and for the adaptation of instruction on the basis of these evaluations. Using background and performance data obtained only with students in the first instructional group, each of whom studied the fundamentals of data processing solely via CAI, analyses were conducted which identified the characteristics of students with whom the CAI materials of each unit were effective. Further, through the use of the Wherry-Doolittle program, regression equations were developed and utilized to predict, prior to instruction, whether the CAI materials were suitable to teach the objectives of each unit to each student in the second instructional group. As those students for whom the CAI materials were judged to be ill-suited received alternative (non-CAI) curriculum materials, instruction was adapted on the basis of the evaluations of materials. Finally, data obtained with students in Group 2 were added weekly to the data bank obtained with Group 1 and the combined data were utilized to produce new, updated Wherry-Doolittle prediction equations. In this way, the system continuously evaluated the effectiveness of the CAI materials and also provided for the adaptation of instruction to individual students on the basis of these evaluations.

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[88] Lawrence Stolurow, "SOCRATES: System for Organizing Content to Review and Teach Educational Subjects," _Seventeenth Annual Industrial Engineering Institute Proceedings_ (1965), 25.

[89] _Ibid_., pp. 34-6.

[90] Bolvin, _op_. _cit_., p. 831.

[91] Brudner, _op_. _cit_., p. 974.

[92] Bundy, _op_. _cit_., p. 345.

[93] McKeegan, _op_. _cit_., p. 235.

[94] Smallwood, _op_. _cit_., p. 8.

[95] Weisgerber, _op_. _cit_., p. 836.

9. The time spent by each student in a given subject area is determined by his performance, rather than by the clock or calendar.

Still another characteristic of a program designed to individualize instruction--the time spent by each student in a given subject area is determined by his performance, rather than by the clock or calendar--is pointed out by Bolvin and Glaser,[96] Coulson,[97] Dean,[98] Shane[99] and Weisgerber.[100] In this investigation, students scheduled themselves for a minimum of two two-hour study sessions a week but were permitted to spend more time (or less time) at each study session. Further, each student continued to study until he had demonstrated mastery of the objectives of each of the six units. Thus, the time spent by a student in the course was determined solely by his performance.

10. The progress of each student is measured by comparing his performance with specific objectives rather than with the performance of other students.

Bolvin,[101] McKeegan,[102] Ullmer[103] and Weisgerber[104] point out that since the aim of a program designed to individualize instruction is to effect a greater degree of mastery of specified objectives by a larger number of students, the progress of each student should be measured by comparing his performance with specific objectives rather than with the performance of other students. In this study, the

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[96] Bolvin and Glaser, op. cit., p. 830.

[97] John Coulson, "Automation, Electronic Computers and Education," Phi Delta Kappan, 47 (March, 1966), 340.

[98] Dean, op. cit., p. 198.

[99] Shane, op. cit., pp. 58-60.

[100] Weisgerber, op. cit., p. 838.

[101] Bolvin, op. cit., p. 238.

[102] McKeegan, op. cit., p. 237.

[103] Ullmer, op. cit., p. 16.

[104] Weisgerber, op. cit., pp. 836-7.

progress of each student was measured solely by comparing his performance with criteria of successful mastery of objectives defined by the investigator. Only when a student answered correctly at least fifty percent of the questions pertaining to given objectives, or scored sixty percent or higher on a unit test which measured the objectives of a sixth of the course, did he progress to the next segment of the course.

11. Students pursue their objectives individually, with small groups of classmates or with their teachers.

The Aerospace Education Foundation,[105] Bolvin,[106] Brudner,[107] Hicken[108] and others[109,110,111] define still another characteristic of a program designed to individualize instruction: students pursue their objectives individually, with small groups of students or with their teachers. In this investigation, no teachers were employed to teach data processing and as subjects elected schedules suited to their particular needs, students pursued their objectives solely on an individual basis.

12. Students have, in writing, the behavioral objectives they are to master.

Various educators[112,113,114,115] concerned with the question of how to individualize instruction effectively state that students must have, in writing, a statement of the behavioral objectives they are to master. Thus, in this investigation, each student was provided with a written list of the behavioral objectives of each unit, prior to his commencement of instruction in that unit.

13. Provision is made for the student to bypass a segment (or part of a segment) of instruction upon demonstration of competence in the subject matter covered by the instructional material.

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[105] Aerospace Education Foundation, _op_. _cit_., p. 1.

[106] Bolvin, _op_. _cit_., p. 239. [107] Brudner, _op_. _cit_., p. 971.

[108] Hicken, _op_. _cit_., pp. 6, 154.

[109] Parker and Russell, _op_. _cit_., pp. 168-173.

[110] Weisgerber, _op_. _cit_., p. 837. [111] Dean, _op_. _cit_., p. 198.

[112] Aerospace Education Foundation, _op_. _cit_., p. 1.

[113] Bolvin, _op_. _cit_., p. 113. [114] Brudner, _op_. _cit_., p. 974.

[115] Ullmer, _op_. _cit_., p. 13.

Blake and McPherson,[116] Ullmer[117] and Weisgerber[118] recommend that provisions be made in programs of individualized instruction for the student to bypass segments of instructional material if he can demonstrate mastery of the objectives taught by the material. In this investigation, students were naive in the subject matter of the course when they initially studied its instructional material. Thus, provisions were made for students to bypass segments of each unit only upon review of the unit. A student required to restudy a section of the course was given the opportunity to bypass parts of the instructional material by correctly answering pretest questions, thereby demonstrating competence in the segments which compose the unit.

14. Teachers encourage students to help determine the materials they work with and the procedures they follow.

This last characteristic of a program of individualized instruction, defined by Jarolimek[119] and Weisgerber,[120] is not included in the system utilized in this study. The rationale for its exclusion stems from the fact that the investigation was designed to determine whether the management system could identify empirically the instructional materials and strategies best suited to the needs and abilities of each subject. This goal could not have been achieved if students had been permitted to determine the materials and procedures to study and employ.

In sum, fourteen characteristics of programs of individualized instruction were identified by the investigator in a search of the literature. Since the management system of this study possesses all but one (number 14) and part of two others (numbers 3 and 5) of these characteristics, the researcher concludes that the system, as designed, effects a program of individualized instruction.

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[116] Blake and McPherson, _op_. _cit_., p. 64.

[117] Ullmer, _op_. _cit_., p. 16.

[118] Weisgerber, _op_. _cit_., p. 839.

[119] Jarolimek, _op_. _cit_., pp. 136-141.

[120] Weisgerber, _op_. _cit_., p. 837.

# 7

# A RESEARCH DESIGN TO TEST THE SYSTEM

*An examination of the capability of the Adaptive Instructional Management System to optimize instruction.*

# A RESEARCH DESIGN TO TEST THE SYSTEM

## Table of Contents

I. A RESEARCH DESIGN TO TEST THE SYSTEM .................... 1

- A. Scope .......................................... 1
- B. The Problem and Subordinate Problems .............. 1
- C. Definition of Terms ............................ 2
- D. Delimitations .................................. 8
- E. Assumption ..................................... 9
- F. Hypotheses ..................................... 9

II. METHODS AND PROCEDURES .............................. 10

- A. The Setting and Subjects ......................... 11
- B. Data Collection on Learning Characteristics ....... 12
- C. The Course: Content and Structure ................ 13
- D. The Instructional Media .......................... 15
- E. The Conduct of the Experiment .................... 15

III. AIMS APPLIED TO THE DATA PROCESSING COURSE ............ 16

- A. The Data Storage Routines ........................ 16
- B. The Data Collection Routines ..................... 18
- C. The Data Analysis Routines ....................... 18

IV. RESULTS ............................................. 23

- A. The Identification of Characteristics Related to Success and Failure with Specific Instructional Material ................................. 23
- B. The Selection and Construction of Alternative Instructional Materials: Application of Experimental Results ............................ 28
- C. Effect of the Computer Management System on Student Performance ............................. 31

V. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS ............ 33

VI. REFERENCES ........................................... 47

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# A RESEARCH DESIGN TO TEST THE SYSTEM

## Table of Figures

TABLE I .....25

TABLE II .....26

TABLE II (continued) .....27

TABLE III .....29

TABLE III (continued) .....30

TABLE IV .....34

TABLE V .....35

TABLE VI .....35

TABLE VII .....35

# I. A RESEARCH DESIGN TO TEST THE SYSTEM

The study described herein was conducted by Dr. Barbara Weinschel to test, with one course of instruction, the ability of the AIMS system to individualize and optimize instruction. A major portion of the research effort involved a thorough review of the literature in an attempt to identify the widely accepted characteristics of a system of individualized instruction. The result of the literature search was the identification of the fourteen points previously reported in Unit VI, virtually all of which were satisfied by AIMS as it was designed and implemented with courses of instruction in this project.

Once a verification of the ability of AIMS effectively to individualize instruction was completed, it remained to test the ability of the system to improve instruction through the individualization of instruction. This chapter describes the general methods and procedures of the experimental research conducted to effect that task. Further, it presents information on the nature of the course and the methods of instruction that are necessary for a complete understanding of how AIMS was applied to the data processing course of instruction at the New York Institute of Technology.

## A. SCOPE

The scope of the investigation hereinafter described was to implement and test a computer-based management system in an effort to provide an empirical, systematic solution to the problem of the effective management of resources in one subject matter area--that of data processing. The research, vital for reasons previously described, was all the more important in view of the fact that to date, there has been a comparative lack of computer applications which combine diagnostic, predictive, instructional and evaluative techniques into an integrated plan for the management of instruction.[1] The investigation here described represents one of the relatively few systematic applications of the computer to the problem of instructional management and the individualization of instruction, thus attempting to meet a critical need of the educators of today.

## B. THE PROBLEM AND SUBORDINATE PROBLEMS

Specifically, the problem of the investigation described here was to demonstrate the ability of an adaptive computer-based management system to improve the overall performance of successive groups of students by individualizing instruction in a multi-media data processing course, and to investigate the learner characteristics or variables which contributed to the successful operation of the management system in this context.

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[1] Richard Wing and others, The Production and Evaluation of Computer-Based Economics Games for the Sixth Grade (Yorktown Heights, New York: The Board of Cooperative Educational Services, First Supervisory District, Westchester County, New York, 1967), p. 10.

In order to accomplish the above, the research was subdivided into the following subordinate problems:

1. To define in detail the computer-based management system utilized to direct a learner with specified characteristics through instructional material with specified characteristics.

2. To verify as individualized instruction the strategies utilized by the computer-based management system to direct a learner with specified characteristics through instructional material with specified characteristics.

3. To demonstrate that a computer-based management system could isolate from a specified list of characteristics those learner characteristics which were significantly related to success and failure in given instructional segments of the data processing course, and which therefore had to be included as components of the prediction model and the decision processes by which students were directed through given instructional materials.

4. To select or construct alternative instructional materials designed to teach a given learning objective or set of learning objectives to students possessing the characteristics related to failure with existing instructional materials.

5. To demonstrate the ability of the computer-based management system to improve the performance of successive groups of students in a multi-media data processing course.

## C. DEFINITION OF TERMS

In order to facilitate an understanding of the research, certain terms must be defined. Note that the definitions presented herein have been limited to this investigation; for example, while there are computers which are not digital and prediction models which involve statistical techniques other than multiple correlation, the definitions of these terms have been confined to their usage in this study.

1. Computer: In this study the term computer refers to the automatic digital computer, defined as a "machine capable of performing numerical and logical manipulations . . . on the basis of wired or initially stored instructions . . . using numbers expressed in digits and in a scale of notation."[2]

2. Computer-assisted instruction: The term computer-assisted instruction (CAI) refers here to the use of the computer to disseminate programmed instruction materials to students on an individual basis. Computer programs were employed continually to analyze the responses of students to the programmed materials and to adapt the presentation of these materials to each student on the basis of his performance or learning history. In this investigation, computer-assisted instruction is distinguished from computer-managed instruction, which is defined simply as a course of instruction directed by the computer in the manner described immediately below.

3. Computer management of instruction: The term computer management of instruction refers to the use of a computer to direct the conduct of the instructional process. Specifically, some of the computer data collection, storage and analysis routines included in this investigation for the direction or management of the human, material and machine resources of instruction were designed to accomplish:

    a) The diagnosis of the strengths and weaknesses of each learner relevant to achievement in the multi-media data processing course;

    b) The prediction of the instructional materials and strategies best suited to the needs, interests and abilities of the individual learner in the multi-media data processing course;

    c) The presentation of or referral to the specific instructional materials judged to be suited to the needs, interests and abilities of the individual student in the multi-media data processing course;

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[2] Harold Borko, "Glossary of Computer Terms," Computer Applications in the Behavioral Sciences, Harold Borko, editor (Santa Monica: System Development Corporation, 1962), pp. 611-612.

  d) The evaluation of the effectiveness of the instructional materials and decision processes by which students are directed through the instructional materials of the course; and

  e) The determination and indication of the need for revision or the addition of multi-media instructional materials and strategies in the data processing course.

4. Course: The term course refers to instructional materials--programmed instructional materials, slides, tapes, films, film-strips and printed materials--dealing with the fundamentals of data processing systems.

5. Data processing: Data processing is defined as "the gathering, storing and processing of numerical and alphabetic information of a business or scientific nature."[3]

6. Decision processes: The term decision processes refers to the strategies or plans of action utilized to individualize and thus to improve instruction. Such strategies or plans involved at a minimum:

  a) The specification of learning objectives to be achieved;

  b) The determination of where in the course of instruction to evaluate learning;

  c) The utilization of examinations designed to evaluate the degree to which learning objectives are achieved;

  d) The specification of criteria,[4] or standards by which terminal behavior, or "the behavior you would like your learner to be able to demonstrate after instruction"[5] is evaluated; and

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[3] Donald P. Ely (ed.), "The Changing Role of the Audiovisual Process in Education: A Definition and a Glossary of Related Terms," Audiovisual Communication Review, 11 (January-February, 1963), 44.

[4] Robert Mager, Preparing Objectives for Programmed Instruction (Palo Alto: Fearon Publishers, Inc., 1962), p. 2.

e) The specification of how to deal with students who (1) meet and (2) fail to meet the criteria defined for mastery of a single, or set of, learning objective(s).

7. Improvement of instruction: In this investigation the term improvement of instruction is defined as the empirical demonstration of significantly increased performance of successive groups of students in the multi-media data processing course.

8. Individualization of instruction: Individualization of instruction is defined as "the organization of instructional materials in a manner that will permit each student to progress in accordance with his own abilities and interests."[6] In this study, individualization of instruction is defined as the "planning and implementation of a . . . program of studies tailored to each student's learning needs based on his competencies and his characteristics as a learner."[7] It is stressed that individualization of instruction as defined here does not restrict the educator, in general, nor the researcher, in this study, to instruction in the individual, or "independent" mode. Instruction may be effected in a group modality and still permit the individualization of instruction as long as the program of studies is responsive to and tailored to the individual needs of each student in the group.

9. Learner characteristics or variables: The terms learner characteristics or learner variables refer to selected factors which are features of, and thus describe and distinguish, students. In this investigation, these factors are classified into (1) performance attributes such as scores on examinations, homework problems and responses to programmed or other instructional materials, and, after

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[5] Ibid., p. 2.

[6] Carter Good, Dictionary of Education (New York: McGraw-Hill, Inc., 1959), p. 290.

[7] John Bolvin, "Implications of the Individualization of Instruction for Curriculum and Instructional Design," Audiovisual Instruction, 13 (March, 1968), 238.

Lavin,[8] (2) intellective, (3) personality and (4) sociological traits. Examples of intellective factors as given in Lavin are IQ measures, general scholastic aptitude examination scores or ranks, prior scholastic performance and specific aptitude examination scores or ranks.[9] Measures of independence, introversion, achievement motivation and cognitive style are examples of personality traits.[10] Finally, socioeconomic status, sex, marital status and age are examples of sociological variables.[11]

10. Learning objective: The term learning objective is defined as a desired "instructional goal defined in terms of both subject-matter content and . . . student behavior."[12]

11. Media, or educational media: The term media is defined as "those things which are manipulated, seen, heard, read or talked about [such as slides, films, tapes] plus the instruments which facilitate such activities."[13]

12. Multi-media: In this study the term multi-media refers to the utilization of more than one educational medium, either in series or simultaneously, to effect a specified learning objective or set of objectives.

13. Multi-media course: The term multi-media course as used in this investigation is defined as instruction which employs a "methodology based on the principle that a variety of . . . media and experiences correlated with other instructional materials overlap and reinforce the value of each other. Some of the material may be used to motivate interest;

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[8] David Lavin, The Prediction of Academic Performance (New York: Russell Sage Foundation, 1965), p. 13.

[9] Ibid., pp. 47-63.

[10] Ibid., pp. 64-121.

[11] Ibid., pp. 122-157.

[12] Robert Glaser, "The Design of Instruction," The Changing American School: Sixty-fifth Yearbook of the National Society for the Study of Education, Part II (Chicago, Illinois: The National Society for the Study of Education, 1966), p. 241.

[13] Barry Morris (ed.), "The Functions of Media in the Public Schools," Audiovisual Instruction, 8 (January, 1963), 11.

others to communicate basic facts; still others to clear up misconceptions and to promote deeper understanding."[14]

14. Prediction: Good defines statistical prediction as the "determination of the most probable level of success in a given task, based upon values of one or more independent variables."[15] In this study, the term prediction refers to the determination of (1) success or failure on a given unit test, and (2) the instructional materials and strategies most likely to effect success in a given task (learning objective) rather than the determination of an actual level of success in a given task.

15. Prediction model: The term prediction model refers here to the computer procedure which applied a multiple correlation statistical technique (1) to predict success or failure on a given unit test, and (2) to distinguish from a group of instructional materials designed to achieve a given learning objective, that set of materials with which a student with specified characteristics is most likely to succeed.

16. Programmed instruction: Programmed instruction is defined as instruction characterized by all of the following elements:

    a) The student is required to respond actively (overtly and covertly) to materials presented;

    b) Instruction is presented in steps in which careful control of stimuli produces gradual increments in mastery of the subject;

    c) The student receives immediate feedback for each response;

    d) Instruction is self-paced so that the rate at which the learner masters the material is individualized;

    e) Materials are field-tested prior to use on a broad scale.

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[14] Ely, *op. cit.*, p. 61, p. 44.

[15] Good, *op. cit.*, p. 408.

## D. DELIMITATIONS

In order to contain or restrict the problem, the following delimitations on the investigation were included:

1. The students participating in this investigation were restricted to those possessing no previously diagnosed learning deficiencies. Those students who were required by their respective high school or college to participate in such special courses of instruction designed to alleviate learning deficiencies as remedial reading, remedial mathematics or remedial science were excluded from the study. The rationale for this delimitation stemmed from the fact that the instructional materials of the data processing course of this investigation were designed for students who possess at least a tenth grade reading, mathematics and science comprehension level.

2. The subjects participating in this study were delimited at a lower bound to individuals who have completed the sophomore year of high school. This restriction stemmed from the fact that the materials presented in this data processing course were designed for students who possess at least a tenth grade reading, mathematics and science comprehension level. Further, the concepts presented in the course are not usually taught at lower grade levels.

3. The learner characteristics or learner variables to be included in the management system of the proposed investigation as potential predictor variables--factors possibly related to learning in the multimedia data processing course--were restricted to selected intellective, sociological, personality and performance factors which can be readily measured using (1) a published, standardized measuring instrument currently available for use by the investigator, (2) an inquiry form designed by the investigator to be completed by the student, and (3) learning evaluation instruments included in the data processing course. The rationale for this delimitation stemmed from the impracticality of attempting to (1) identify, and (2) reliably and validly measure all the factors that may be related to learning in any course of instruction, and from the fact that an adequate number of instruments exist to measure factors in the major areas with which this study is concerned.

4. Assessment of the effects and effectiveness of the computer-based management system was confined in this study to the determination of whether the system could improve instruction and learning with successive groups of students in a data processing course.

## E. ASSUMPTION

In conducting the investigation, the assumption was made that the particular type of computer system utilized in this investigation would not affect the results of the study; similar results would be obtained utilizing similar computer systems--systems in which input-output and processing times, storage capacities and equipment are similar.

## F. HYPOTHESES

Finally, two hypotheses were tested in this study. These hypotheses were derived from earlier research performed by the author,[16] and from the writings and research of other educators[17,18] who have applied the computer to the problems of the individualization and optimization of instruction. The hypotheses tested in this investigation were:

1. A computer-based management system could isolate from a specified list of characteristics those learner characteristics which were related to success and failure in given instructional segments of the data processing course.

2. The adaptive computer-based management system, whose decision processes were modified on the basis of performance data on all past students as it "learned" about the effects of its decisions, could improve the performance of successive groups of students in a multi-media data processing course: the performance of the second group of pupils would be greater than that of the first group.

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[16] Barbara Schure [Weinschel], "The Computer: An Adaptive Teacher," Some Essays on Computers in Education (Cambridge, Massachusetts: New England School Development Council and the Graduate School of Education, Harvard University, 1967), pp. 47-63.

[17] Walter Dick, "The Development and Current Status of Computer-Based Instruction," American Educational Research Journal, 2 (January, 1965), 41-54.

[18] Richard Smallwood, A Decision Structure for Teaching Machines (Cambridge, Massachusetts: The MIT Press, 1962).

## II. METHODS AND PROCEDURES

The general methods and procedures of the experimental research designed to test the effectiveness of the system, can be summarized as follows:

The investigator

1. employed a computer-assisted instruction (CAI) course in the fundamentals of data processing which was written and validated by IBM as the program of instruction through which the ability of AIMS to improve instruction was tested;

2. administered to the two groups of subjects, prior to the commencement of instruction by each group, a battery of examinations and a personal data form which were designed to measure selected aptitude and personality characteristics;

3. utilized the CAI course of instruction as the sole educational resource for the students in the first instructional group;

4. established relationships between the aptitude and personality characteristics of students and success and failure in the CAI course as reflected by scores obtained on the six unit tests included by IBM in the course of instruction;

5. utilized the relationships identified in (4) in the selection and construction of a complete set of non-CAI instructional materials, designed by the investigator to teach the learning objectives of the data processing course to students possessing the characteristics related to failure with the CAI materials of instruction;

6. retaught the fundamentals of data processing to a second group of students, using AIMS to monitor progress and two sets of instructional materials--one CAI and the other non-CAI;

7. compared the performance of the two instructional groups in order to assess the effectiveness of the management system.

## A. THE SETTING AND SUBJECTS

The investigation was conducted at the Old Westbury, New York, campus of the New York Institute of Technology, the location of the IBM 1500 Instructional System and IBM System/360, Model 30 computer which were utilized in the study. Participation of the secondary schools and colleges in the study was limited to those located on Long Island in order to facilitate easy access to the instructional terminals of the system.

The investigator considered as potential subjects all individuals at the participating colleges and secondary schools who completed the sophomore year of high school and who possessed no diagnosed serious learning deficiencies which required remediation at the time of the study. It was then necessary to select from this population of potential participants for inclusion in the study only those individuals who possessed no prior knowledge of data processing. To accomplish this task, the investigator administered as a pretest the final examination for the Fundamentals of Data Processing course. The test, the January, 1968 revision of the Fundamentals of Data Processing Systems Course Examination, developed by IBM to accompany the course, is composed of fifty-four items designed to measure the mastery of concepts covered in the program of instruction.

## B. DATA COLLECTION ON LEARNING CHARACTERISTICS

Two major functions of AIMS were (1) to use data obtained with one group of students (Group 1) to identify the variables related to learning in the CAI course, and (2) to predict, on the basis of the relations identified, the instructional materials best suited to the needs and abilities of individual students in a second, successive group (Group 2). In order for the management system to be able to effect these tasks, it was necessary for the investigator to obtain for each subject measures of certain personality, intellective and social characteristics which the researcher thought might relate to learning in a data processing course. A battery of examinations consisting of the following tests and personal data form was thus administered to each subject participating in the investigation for the purpose of measuring the variables described below.

1. The Aptitude Test for Programmer Personnel (ATPP)--a test which yields valid and reliable measures of the programming aptitude of non-IBM personnel.[19]

2. The California Short-Form Test of Mental Maturity (IQ)--a

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[19] Manual for Administering and Scoring the Aptitude Test for Programmer Personnel (White Plains, New York: IBM Corporation, 1964).

test which yields reliable[20] measures of the IQ, language IQ or aptitude and non-language IQ or aptitude of high school and college students and adults.[21]

3. The Edwards Personal Preference Schedule (EPPS)--a test which yields reliable[22] and valid[23] measures of the following fifteen variables: need for achievement, deference (or cooperation), need for order, exhibition, autonomy (or independence), succorance (or dependence), need for affiliation, intraception, need for change, endurance (or perseverance), heterosexuality, dominance, abasement, nurturance and aggression.[24]

4. The Eysenck Personality Inventory--a test designed for use with high school and college students and adults which yields reliable measures of the following three variables: extraversion, lying and neuroticism.[25]

5. The IPAT 8 - Parallel Form Anxiety Battery (IPAT)--a test designed for use with individuals over 15 years of age which yields a reliable and valid measure of the anxiety variable.[26]

6. The Brown-Holtzman Survey of Study Habits and Attitudes (SSHA)--a test "designed to identify students whose study habits and attitudes are not those of students who do well in academic work"[27]

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[20] Julian C. Stanley, in a review of the California Short-Form Test of Mental Maturity, The Sixth Mental Measurements Yearbook, Escar Buros, editor (Highland Park, New Jersey: The Gryphon Press, 1965), p. 696.

[21] Oscar Buros (ed.), The Sixth Mental Measurements Yearbook (Highland Park, New Jersey: The Gryphon Press, 1965), p. 693.

[22] John A. Radcliffe, in a review of the EPPS, The Sixth Mental Measurements Yearbook, Oscar Buros, editor (Highland Park, New Jersey: The Gryphon Press, 1965), p. 195.

[23] Lawrence J. Stricker, in a review of the EPPS, The Sixth Mental Measurements Yearbook, Oscar Buros, editor (Highland Park, New Jersey: The Gryphon Press, 1965), p. 204.

[24] Buros, *op. cit.*, p. 190.

[25] *Ibid.*, pp. 215-216.

[26] Paul Kjeldergaard, in a review of the IPAT 8-Parallel-Form Anxiety Battery, The Sixth Mental Measurements Yearbook, Oscar Buros, editor (Highland Park, New Jersey: The Gryphon Press, 1965), p. 263.

[27] James Deese, in a review of the SSHA, The Fifth Mental Measurements Yearbook, Oscar Buros, editor (Highland Park, New Jersey: The Gryphon Press, 1959), p. 781.

which yields reliable and valid measures of the study habits and attitudes of individuals.[28]

7. The Induction (Figure Classification) Scale of the Educational Testing Service Kit of Reference Tests for Cognitive Factors (I-3)--a test designed to measure the inductive reasoning ability of an individual.[29]

8. An "Inquiry Form"--a two-page personal data form constructed by the researcher to yield information on the following interest and sociological variables: grade level, number of credits or courses taken at the time of the investigation, academic average, sex, marital status, highest level of education attained by father and mother, occupation of father and mother, mean income of parents, interest in a data processing career, interest in a teaching career and academic aspiration or intention.

The personal data form and seven examinations were administered under the standardized conditions described in the manuals of the respective tests. The researcher administered this battery to students in the first instructional group (Group 1) just prior to the commencement of instruction in the course or during the first week of instruction. The measures obtained with this group of students were then utilized to identify the characteristics related to learning the data processing course. The researcher, or certified school psychologists and/or guidance counselors administered the battery under standardized conditions to students in the second group (Group 2). As measures obtained for students in Group 2 were used by the system to predict prior to instruction the materials best suited to the individual learner, these students completed the testing battery at least two weeks prior to the commencement of instruction in the course. The personal data form and seven examinations were scored objectively using the answer keys provided by the respective testing bureaus and a key to the personal data form.

## C. THE COURSE: CONTENT AND STRUCTURE

The course material of this investigation was a six-unit adaptation for the IBM 1500 Instructional System of "The Fundamentals of Data Processing Systems" written in programmed text form by

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[28] C. Gilbert Wrenn and Roy Lewis, in a review of the SSHA, The Fifth Mental Measurements Yearbook, Oscar Buros, editor (Highland Park, New Jersey: The Gryphon Press, 1959), p. 783.

[29] Oscar Buros (ed.), The Sixth Mental Measurements Yearbook (Highland Park, New Jersey: The Gryphon Press, 1965), pp. 853-854.

L. R. O'Neal.[30]

As part of the course, a student was required to take a computer-administered unit test upon completion of each of the six sections of the course. Each of these unit tests was written by the course designers and was included by them in the course to assess the degree to which the learning objectives of the section had been mastered. With the exception of the fifth unit test, the tests for all units consisted of between twelve and twenty multiple-choice, matching and constructed-answer questions; the unit test for the fifth section consisted solely of constructed-answer questions. As designed by IBM, the computer automatically scored the multiple-choice and constructed-answer sections of each unit test separately, giving equal weight to each item in a section of a test. Thus, two scores, each of which ranged from 0 to 100; were obtained for each unit test with the exception of the fifth; only one score which ranged from 0 to 100 was obtained for the fifth unit text. For the purposes of this investigation, however, the two scores obtained by each student on Unit Tests 1,2,3,4 and 6 were summed and then divided by two in order to obtain a single score for each of the six unit tests.

Another feature of the course, designed by IBM, was the requirement that a student who failed to obtain a passing grade on a section of a unit review the instructional material of that unit and take the unit test a second time before progressing to the next unit. This requirement was enforced for the two instructional groups in the study.

As still another feature, the CAI course as designed by IBM presented the investigator with the choice of including "pretest" questions prior to the major subject treatments in each unit. In this study, the pretest questions were included in the presentation of the CAI course only when a student failed a unit test and was required to repeat that section. Such utilization of the pretest question option required that the student review only those sections of instructional material for which he could not demonstrate mastery by correctly answering the pretest questions.

Finally, other features of the course structure as designed by IBM and employed in this investigation are described below:

> Participants completing the course were required to answer correctly a minimum of 733 questions which were supported by an excess of 7000 screen displays. Approximately 500 of these questions were of a

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[30] Leeland R. O'Neal, Electronic Data Processing Systems: A Self-Instructional Manual (Englewood Cliffs: Prentice-Hall, Inc., 1964).

constructed answer format. For each of these contained in tutorial areas of the course, the subject could request systems help beyond that provided by the normal sequence of displays. In response to such requests, the course and system provided one of the following on a pseudo-random basis: (1) a clue to the answer of the question encountered; (2) the answer to the question; (3) no additional assistance.[31]

## D. THE INSTRUCTIONAL MEDIA

For the first group participating in the study, instruction consisted solely of the computer-assisted presentation described above. The subject matter and unit tests were presented by the computer on a cathode ray tube in a programmed instruction format and students communicated with, or responded to, the computer by means of an electronic light pen or a typewriter keyboard.

For the second group in the study, the presentation was modified as follows: instruction was disseminated by the computer, or via films, tapes, textbooks and other printed media designed or selected especially for the course to reflect learning problems indicated by the first instructional group. The new materials provided alternative instructional materials for selected students in Group 2 for whom the management system predicted, prior to instruction in each unit, failure with existing CAI materials for that unit. Thus, while the instructional media utilized with a given student in Group 2 varied according to his specific profile of learning characteristics and his performance in the course, for this group as a whole, instruction was disseminated by a combination of media of which the computer was only one.

## E. THE CONDUCT OF THE EXPERIMENT

Prior to commencing instruction in the course, students were required by the investigator to schedule themselves for two study sessions per week during the hours of 8 A.M. to 9 P.M. on Monday through Friday. Students were permitted and encouraged to schedule themselves for additional study sessions each week, where desired.

The first study session in the experiment for each subject was devoted to an orientation. After their first orientation session in the experiment, students began the independent study course of instruction. Within two days following completion of the last of the six units, the student took the two-hour final examination which had been administered as a pretest. The examination was administered individually to each subject under standardized conditions, and was scored objectively by the investigator. Each final examination score obtained was recorded by the researcher, punched onto cards and stored by the computer in the background file of the respective student.

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[31] Harvey S. Long, "A Determination of the Relation of Total Time for Course Completion to the Duration of the Study Interval in Teaching Via Computer Assisted Instruction" (unpublished Ph.D. thesis, submitted to The School of Education, New York University, New York, 1968), p. 57.

A letter indicating satisfactory course completion was then sent by the investigator to the school or firm of each student who obtained a passing grade on this last of the course requirements.

## III. AIMS APPLIED TO THE DATA PROCESSING COURSE

This section describes in detail the components of AIMS as they were utilized in this experimental study: data storage, collection and analysis routines which were involved in (1) the evaluation of learning, (2) the presentation of or referral to specific instructional materials, (3) the diagnosis of the strength and weaknesses of each learner relevant to achievement in the multi-media data processing course, (4) the indication of the need for revision or the addition of multi-media instructional materials and strategies, (5) the prediction of the instructional materials and strategies best suited to the needs of the individual learner and (6) the determination of the ability of the management system to improve learning and to identify the variables related to learning in the data processing course. The following is a description of these programs.

### A. THE DATA STORAGE ROUTINES

The data storage routines were concerned primarily with recording and storing in the management system permanent information which was available prior to the commencement of instruction with each group. They were designed to accomplish the tasks described below:

1. The storage in the student background file of the measures of personality, intellective and sociological variables obtained with each student through the administration of the testing battery described above.

2. The storage of the criteria of success and failure used to evaluate learning. In this investigation, learning was assessed by comparing the performance of a student on questions in the instructional material or in unit tests with criteria of success defined by the researcher. The investigator thus specified the following criteria of success which were input to and stored by the system: a score of sixty percent as the minimum passing or successful score on a unit test and a score of fifty percent

as the minimum passing or successful score on the instructional materials questions pertaining to a specified set of learning objectives. These stored criteria of success were referenced by the programs which evaluated learning.

3. The storage of a table which keyed every question in the instructional materials of the course to a particular learning objective or set of learning objectives. In order to facilitate the system's evaluations of the student's mastery of these learning objectives, the investigator constructed a table or list which identified and linked every question in the course with the learning objective or set of objectives that question was designed to test. This table was input to the computer and stored so that it could be utilized by the data analysis program which evaluated learning.

4. The storage of a table of referrals to remedial instructional material. In order to permit the management system to make referrals to remedial instructional materials in an attempt to alleviate the learning difficulty before unit tests, the investigator constructed and stored in the computer tables which listed the instructional materials to be studied by students who failed to master particular learning objectives. These tables were used by the data analysis program which evaluated learning and directed students through the instructional materials of the course.

5. The storage of lists of instructional materials to be prescribed to students who master the learning objectives of a unit. When a student in Group 2 successfully completed the material of a given unit, the computer management system determined the most suitable instructional material for his study of the next unit and then produced a list of these instructional materials for the student. In order to facilitate the generation by the management system of the instructional materials lists, the investigator constructed and stored in the computer: (1) a table which listed the materials for each unit to be studied when a prediction of success with CAI materials is obtained; and (2) a table which listed the materials to be studied when a prediction of failure with CAI materials is obtained. These tables were utilized by the data analysis program which evaluated learning and directed students through the course.

## B. THE DATA COLLECTION ROUTINES

The data collection routines were concerned with the collection, recording and storage of data that became available during the course of instruction. These data were analyzed and summarized by the data analysis routines and were not a permanent part of computer storage. The routines were designed to accomplish the following:

1. To collect and record student responses to CAI materials.

2. To collect and record student responses to unit tests.

## C. THE DATA ANALYSIS ROUTINES

The data analysis routines were concerned with the synthesis and analysis of the data collected and stored prior to and during the course of instruction. As such, the programs were involved in the evaluation of learning and in the direction of a student through the curriculum materials of the course. They were utilized to identify the characteristics of students who succeeded or failed with given instructional materials, and thus to indicate the need for the revision of materials and strategies or the addition of multi-media materials and strategies for specific students. The data analysis routines were used prior to instruction, to predict the course materials and strategies best suited to the needs and abilities of the individual student. Finally, they were utilized to investigate the effectiveness of the computer-based management system designed to improve learning of successive groups in a data processing course.

The following is a description of the data analysis programs.

1. The Correlation Coefficient Computation and Test Program. This program was designed to compute the correlation between each background variable and the scores obtained on each of the six unit tests after the completion of instruction by students in Group 1 and by students in Group 2. Using as input the background and performance data file, the program computed the correlation[32] between each background variable and each unit test. The program

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[32] Using the formula $\frac{\sum_i X_i Y_i - N\bar{X}\bar{Y}}{(N-1) \quad S_x S_y}$ where $X_i$ are the measures of the background variable, $Y_i$ are the unit test scores, N is the total number of students in thr group, $\bar{X}$ is the mean of background variable X, $\bar{Y}$ is the mean of the unit test scores, $S_x$ is the standard deviation of the background variable X and $S_y$ is the standard deviation of unit test Y.

then employed the Fisher r to Z transformation[33] to compute a value, which in turn was used to test hypotheses that each obtained correlation coefficient ($r_{xy}$) equalled zero. Specifically, the program computed a correlation test statistic[34] which indicated the number of standard deviations of the observed correlation from an assumed true correlation of zero. The researcher then utilized the obtained correlation coefficients and test statistics to identify the background variables which were related to success and failure in each unit of the data processing course. (See below for the results.)

2. The Background Data Classification Program. This program was designed to permit the researcher to subdivide each background variable into classes and to examine the relationship between the various classes of the background variable and students' unit test scores. The researcher defined the numerical class intervals into which each background variable was to be divided. Using this information and the student background and performance file as input, the program produced as output the following information for each class of each background variable:

    a. the number of students in each background variable class;

    b. the minimum and maximum unit test score in that class;

    c. the range of responses in that class;

    d. the mean and standard deviation of unit test scores for that class; and

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[33] $Z = \frac{1}{2} \log_e \frac{1 + r_{xy}}{1 - r_{xy}}$

[34] The test statistic $\frac{Z - E(Z)}{\sqrt{1/(N-3)}}$, where 1/(N-3) is the sampling variance of Z and E(Z) = .0000 was referred to a normal distribution at the $\alpha = .05$ level (two-tailed). Thus, a standard score of ±1.96 was required for rejection of the hypothesis that $r_{xy} = 0$.[35]

[35] William L. Hays, Statistics for Psychologists (New York: Holt, Rinehart and Winston, Inc., 1963), pp. 530-1.

e. a list by class, in histogram form, of the unit test score responses of students.

The information obtained with this program was used by the researcher to determine the background variable characteristics of students who failed to master the objectives of each unit with CAI materials.

3. The Wherry-Doolittle Program. This program was designed to select (in order of their contribution to the multiple R) the variables which give the maximum shrunken multiple correlation with a criterion, or unit test score.[36] It took into account the chance error added by each variable and used the Wherry "stop criterion" to determine the point at which the addition of another variable to the multiple correlation added more chance error than actual validity.[37] When this point was reached, no further addition of variables was made by the program.

   The Wherry-Doolittle program utilized in this study was run weekly; the routine used as input each week the student background and performance file of past and then current students to effect the following:

   a. An automatic conversion of the academic average or Quality Point Index (QPI) of college students into a numeric grade or score ranging from 50 to 95;

   b. The computation and output of the means, standard deviations and ranges of each variable, and correlation matrices which indicated the intercorrelations of each background variable with each unit test and with each other;

   c. The choice of an initial regression variable and the computation and output of the shrunken multiple and estimate of error obtained with this variable;

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[36] Nathan Jaspen, "The Wherry-Doolittle Test Selection Method in FORTRAN," Educational and Psychological Measurement, 23 (Autumn, 1963), 599.

[37] Ibid.

d. The determination of whether the Wherry stop criterion was satisfied - that is, whether the addition of another variable to the regression would add more chance error than it would increase the multiple R. If the stop criterion was satisfied, the complete set of regression coefficients was computed and output. If the criterion was not satisfied, another variable was added to the regression, a new shrunken multiple and estimate of error were computed and output and the stop criteria was again applied. The procedure continued until the stop criterion was satisfied and the complete set of regression coefficients was determined and output.

The regression coefficients obtained with Group 1 data by the Wherry-Doolittle routine were utilized by the program described immediately below to predict, prior to instruction, the unit test score that would be obtained by a student in Group 2 if that student studied CAI materials for the unit. The regression coefficients were employed in this identification upon completion of instruction by Group 1 and upon completion of instruction by Group 2, using, respectively, Group 1 and Groups 1 and 2 data, combined.

4. The Student Evaluation and Direction Program. This program was designed to summarize, daily, the performance of students; to compare the performance of a student with the criteria of successful mastery; and to use the results of these comparisons to direct a student to appropriate instructional materials. The routine computed, updated and stored in the background file until the next unit, the percentage of correct answers obtained by each student on questions pertaining to specified sets of learning objectives. Then, for each student in a non-CAI path and for each student in CAI who completed the primary instructional materials of a given unit, the program generated a report which informed the student of his progress and directed him in the following manner to the next step in the course of instruction:

   a. Students in the non-CAI path who mastered the objectives of a segment of a unit were directed to continue their study of non-CAI materials for the next segment of the unit;

b. Students in the non-CAI path who mastered all of the objectives of a unit were directed to take the unit test for that unit;

c. Students in the non-CAI path who failed to master the objectives of a segment of a unit were directed to study specified non-CAI remedial materials before they progressed to the next segment of the unit;

d. Students in the CAI path who mastered all of the objectives of a unit were directed to take the unit test for that unit; and

e. Students in the CAI path who failed to master all of the objectives of a unit were directed to study specified non-CAI remedial materials before they progressed to the unit test.

The Student Evaluation and Direction Program was designed to perform several additional, related tasks. First, the program produced a daily report which informed the researcher of the instructional path and progress to date of each student who studied during that calendar day. Second, the routine used the coefficients produced by the Wherry-Doolittle Program to generate a predicted score on the next unit test for each student who that day completed the instructional material of a given unit. (The predicted score is the score the student would be expected to obtain on the unit test for the next unit if he studied CAI materials for that unit.) Using the predicted score, the computer included in the progress report for a student who successfully completed the instructional materials of a unit a list of curriculum materials judged to be best suited for his study of the next unit. Finally, the Student Evaluation and Direction Program computed and summarized the unit test scores obtained by students during the day and input these scores to the student background file so that unit test scores could be used in the Wherry-Doolittle Program as possible regression variables in future unit test predictions.

5. The Analysis of Covariance Program. This program was designed to assess the ability of the computer management system to improve learning in the data processing course. It was run seven times to assess the ability of the management system to improve learning in each of the six units of the course and on the final examination, respectively. Each time the program was run, it used as covariants the regression variables that

correlated with the unit test score or final test score as determined by the Wherry-Doolittle Program. Thus, the Analysis of Covariance Program insured the statistical equivalence of the two groups while it compared their performance on each of the six unit tests and on the final examination.

The results of this data analysis program were utilized in an attempt to demonstrate that the computer management system was able to improve the performance of successive groups of students in the data processing course.

## IV. RESULTS

The experiment herein described was designed to test the following hypotheses:

1. A computer-based management system can isolate from a specified list of characteristics those learner characteristics which are related to success and failure in given instructional segments of the data processing course; and

2. The adaptive computer-based management system, whose decision processes are modified on the basis of performance data for all past students as it "learns" about the effects of its decisions, can improve the performance of successive groups of students in a multi-media data processing course: the performance of the second group of pupils will be greater than that of the first group.

In this section, tests of each of the above hypotheses are discussed and the results presented. Further, the application of the results of the Wherry-Doolittle program (used to test the first hypothesis) to the selection and construction of alternative instructional materials is discussed.

### A. THE IDENTIFICATION OF CHARACTERISTICS RELATED TO SUCCESS AND FAILURE WITH SPECIFIED INSTRUCTIONAL MATERIAL

The first hypothesis is concerned with the identification from a specified list of learner characteristics of those characteristics related to success and failure in each unit of the course as taught by specified instructional materials. Specifically, the hypothesis is concerned with the identification of characteristics related to success and failure in each unit as taught by the CAI and by the non-CAI materials utilized in the course. However, on the basis of the predicted scores generated by the Wherry-Doolittle regression equations (using Group 1 data), the management system judged the CAI materials to be suitable for the study of Units One, Two, Three and Four by all of the 119 students in Group 2. Thus, the 119 students in the second group utilized CAI materials for their study of the first four units; no student in this second instructional group utilized the non-CAI materials as the primary resource for Units One, Two, Three or Four. Further, only eleven students in the second instructional group employed the non-CAI materials as the primary resource for Unit Five and only six students in the second instructional group employed the non-CAI materials as the primary resource for Unit Six. The use of non-CAI materials by such a small sample size precludes, at this time, the meaningful identification of characteristics related to success and failure with these alternate instructional materials. The test of Hypothesis 1 is thus limited to the identification of variables related to learning with CAI materials. Table I presents the complete list of learner characteristics and the source of each variable measure from which learner variables related to success and failure in each of the six units as taught by CAI were isolated.

The procedure employed to identify the variables related to success and failure in the course as taught by CAI material consisted first of the computation of a Pearson product-moment correlation coefficient between each background variable listed in Table I and the scores obtained on each of the six unit tests by students who utilized the CAI materials. Second, for each correlation coefficient, a correlation test statistic which indicated the number of standard deviations the observed correlation was from an assumed true correlation of zero was computed. The test statistic was referred to a normal distribution at the $\alpha = .05$ level (two-tailed), where a standard score of $\pm 1.96$ was required for rejection of the hypothesis that $r_{xy} = 0$.

The correlation coefficients were computed and tested after the completion of instruction by students in the first instructional group (Group 1) and by students in the second instructional group (Group 2). In preparation for the testing of Hypothesis 1, data obtained with the students in the second group who studied non-CAI materials for Units Five and Six were temporarily excluded from the background and performance data file.

The results of the correlation coefficient and test statistic program obtained for each unit of the course are summarized in Table II which depicts the significant variables for each of the six units as determined by tests of Pearson product-moment correlation coefficients which were performed upon completion of instruction by Group 1 and again upon completion of instruction by Group 2. As shown in the Table, nine variables were determined to be related to learning in Unit One upon completion of instruction by the first group of 115 students, all of whom studied CAI materials. Upon completion of instruction by the second group of (119) students, all of whom studied

## TABLE I

## LIST OF LEARNER VARIABLES TESTED FOR RELATION TO LEARNING IN EACH UNIT OF COURSE

| VARIABLE NAME | SOURCE OF VARIABLE |
|---|---|
| Grade Level | Student Inquiry Form |
| Number of Credits | Student Inquiry Form |
| Sex | Student Inquiry Form |
| Marital Status | Student Inquiry Form |
| Age | Student Inquiry Form |
| Father's Education | Student Inquiry Form |
| Mother's Education | Student Inquiry Form |
| Mean Income | Student Inquiry Form |
| IQ | California Short-Form Test of Mental Maturity |
| Language Aptitude | California Short-Form Test of Mental Maturity |
| Non-Language Aptitude | California Short-Form Test of Mental Maturity |
| Programming Aptitude | Aptitude Test for Programmer Personnel |
| Achievement | Edwards Personal Preference Schedule |
| Autonomy | Edwards Personal Preference Schedule |
| Dependence | Edwards Personal Preference Schedule |
| Dominance | Edwards Personal Preference Schedule |
| Need for Change | Edwards Personal Preference Schedule |
| Endurance | Edwards Personal Preference Schedule |
| Aggression | Edwards Personal Preference Schedule |
| Neuroticism | Eysenck Personality Inventory |
| Lie | Eysenck Personality Inventory |
| Inductive Reasoning | ETS Induction (Figure Classification) Scale |
| Extraversion | Eysenck Personality Inventory |
| Anxiety | IPAT 8-Parallel Form Anxiety Battery |
| Deference | Edwards Personal Preference Schedule |
| Need for Order | Edwards Personal Preference Schedule |
| Exhibitionism | Edwards Personal Preference Schedule |
| Affiliation | Edwards Personal Preference Schedule |
| Intraception | Edwards Personal Preference Schedule |
| Abasement | Edwards Personal Preference Schedule |
| Nurturance | Edwards Personal Preference Schedule |
| Heterosexuality | Edwards Personal Preference Schedule |
| Study Habits | Brown-Holtzman Survey of Study Habits and Attitudes |
| Interest in Teaching Career | Student Inquiry Form |
| Interest in Data Processing Career | Student Inquiry Form |
| Academic Average | Student Inquiry Form |
| Unit Test 1 Scores | Unit Test 1 |
| Unit Test 2 Scores | Unit Test 2 |
| Unit Test 3 Scores | Unit Test 3 |
| Unit Test 4 Scores | Unit Test 4 |
| Unit Test 5 Scores | Unit Test 5 |
| Unit Test 6 Scores | Unit Test 6 |

## TABLE II

## SUMMARY OF STUDENT VARIABLES RELATED TO SUCCESS AND FAILURE IN EACH UNIT OF COURSE AS DETERMINED BY TESTS OF CORRELATION COEFFICIENTS: GROUP 1 AND GROUPS 1 AND 2

| | GROUP 1 | | | | | | GROUPS 1 & 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable Name | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 |
| Grade | x | | | | | | | | | | | |
| Credits | x | x | x | x | x | x | | x | x | x | x | x |
| Sex | | | x | | | | | | x | | | |
| Marital Status | x | x | | | | x | | | | | | |
| Age | | x | | | | | | | | x | | |
| Father's Education | | x | | | | | | x | | x | x | x |
| Mother's Education | | | | | | | | | | | | |
| Income | | | | | | | | x | x | x | | x |
| IQ | x | x | | | x | | x | x | x | x | x | x |
| Language Aptitude | | x | | | x | | x | x | x | x | x | x |
| Non-Lang. Aptitude | x | | | | x | x | x | x | | | | x |
| Program. Aptitude | x | x | x | | x | | x | x | x | x | x | |
| Achievmnt | | | x | | | | | | | x | | |
| Autonomy | | | | | | | | | | | | |
| Dependence | x | | x | | | | | | x | | x | x |
| Dominance | | | | | | | | | x | x | | |
| Change | | | | | x | x | | | | | | |
| Endurance | x | x | x | x | | | x | | x | x | | |
| Aggression | | | x | | | | | x | x | | | |
| Neuroticsm | | | | | | | | | x | | | |
| Lie | | | | | x | | | | | | | |
| Inductive Reasoning | | x | x | | x | | | x | x | x | x | x |
| Extraversn | | x | | x | x | x | | x | | x | | x |
| Anxiety | | | | | | x | | x | | x | x | |
| Deference | | | | x | | x | x | | | | x | x |
| Order | | | | | | | x | | | x | x | |
| Exhibition | | | | x | x | | | | | x | | |
| Affiliatn | | | x | x | | | | | x | | x | |
| Intraceptn | | | | | | | | | | | | |
| Abasement | | | | | | x | | | | x | | |
| Nurturance | | x | x | x | | | | x | x | x | x | |

TABLE II (continued)

| | GROUP 1 | | | | | | GROUPS 1 & 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable Name | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 |
| Hetero-sexuality | x | | | | x | | x | | | | | |
| Study Habits | | x | | | x | x | | x | | x | x | |
| Data Proc. Interest | | | | | | x | | x | x | | x | |
| Teaching Interest | | x | x | | | x | x | x | x | x | | |
| Academic Average | | x | | | x | x | x | x | x | x | x | x |
| Unit Test 1 | NA | NA | x | x | | | NA | NA | x | x | | x |
| Unit Test 2 | NA | NA | NA | x | x | | NA | NA | NA | x | x | x |
| Unit Test 3 | NA | NA | NA | NA | x | | NA | NA | NA | NA | | |
| Unit Test 4 | NA | NA | NA | NA | NA | | NA | NA | NA | NA | NA | x |
| TOTALS | 9 | 14 | 12 | 9 | 15 | 12 | 10 | 16 | 18 | 22 | 16 | 14 |

CAI materials, ten variables were determined to be related to learning. Thus, the computer-based management system was capable of isolating from the specified list of characteristics those learner characteristics which were related to success or failure in Unit One of the course as taught by CAI materials.

As shown in the Table, fourteen variables were determined to be related to learning in Unit Two upon completion of instruction by the first group of 115 students. Analysis conducted upon completion of instruction by the second group of 119 students (all of whom studied CAI materials) on the combined data of Groups 1 and 2 identified sixteen variables related to learning. Thus, the computer management system was capable of isolating learner characteristics related to success and failure in Unit Two of the course as taught by CAI materials.

Similarly, upon completion of instruction by the first group of students, twelve and nine variables were determined to be related to learning in Units Three and Four, respectively. Upon completion of instruction by the second group of 119 students, all of whom studied CAI materials, eighteen and twenty-two variables were determined to be related to learning in Units Three and Four, respectively. Thus, the computer management system was capable of isolating learner characteristics related to success and failure in Units Three and Four of the course as taught by CAI materials.

As shown in Table II, upon completion of instruction by the first group of students, fifteen variables were determined to be related to learning in Unit Five. Upon completion of instruction by the second group of students, 108 of whom studied CAI materials yielding a combined N of 115 + 108 = 223, sixteen variables were determined to be related to learning. The computer management system was thus able to isolate the learner characteristics related to success and failure in Unit Five of the course as taught by CAI materials.

Finally, as shown in the Table, upon completion of instruction by the first group of students, twelve variables were determined to be related to learning in Unit Six. Upon completion of instruction by the second group of students, 113 of whom studied CAI materials yielding a combined N of 115 + 113 = 228, fourteen variables were determined to be related to learning. The computer management system was thus able to isolate the learner characteristics related to success and failure in Unit Six of the course as taught by CAI materials.

In sum, the data presented in Table II provide the basis for support of the hypothesis that the computer-based management system can isolate from a specified list of characteristics those learner characteristics which are related to success and failure in each of the six units of the data processing course as taught by CAI materials.

## B. THE SELECTION AND CONSTRUCTION OF ALTERNATIVE INSTRUCTIONAL MATERIALS: APPLICATION OF EXPERIMENTAL RESULTS

The fourth of the five sub-problems of this investigation involved the selection or construction of alternative instructional materials designed to teach a given learning objective or set of objectives to students possessing the characteristics related to failure with the CAI instructional materials. This section describes how the results of the Wherry-Doolittle Program and of the program which computed and tested correlation coefficients were combined and utilized to solve this sub-problem.

In order to select or construct alternative instructional materials designed to teach objectives to students possessing the characteristics related to failure with CAI materials, it was necessary to identify the characteristics of students who failed to master objectives with the CAI materials. The results of the two abovementioned statistical procedures were employed upon completion of instruction in the course by the students in each of the two instructional groups to accomplish this task. First, the variables determined to be related to learning by the correlation coefficient computation and testing procedure were listed. Second, the variables determined by the Wherry-Doolittle Program to give the maximum shrunken correlation with each unit test score were listed. Table III summarizes

## TABLE III

## SUMMARY OF STUDENT VARIABLES RELATED TO SUCCESS AND FAILURE IN EACH UNIT OF COURSE AS DETERMINED BY THE WHERRY-DOOLITTLE PROGRAM: GROUP 1 AND GROUPS 1 AND 2

| | GROUP 1 | | | | | | GROUPS 1 & 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable Name | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 |
| Grade | x | | x | | | | | x | | | | |
| Credits | x | | | x | | | | x | | x | | x |
| Sex | x | | x | | | | | x | | | x | |
| Marital Status | x | x | | | x | | | x | | x | | |
| Age | x | x | | x | | | | | | | x | |
| Father's Education | | | x | | | x | | | | | | x |
| Mother's Education | x | | | | | x | x | | | x | | |
| Income | | x | | | | | | | x | x | | x |
| IQ | | | | | x | | | | | | | |
| Language Aptitude | | x | | | | | | | | x | | |
| Non-Lang. Aptitude | | x | x | | | x | x | | x | x | | x |
| Program. Aptitude | x | x | x | x | | x | x | x | x | x | | |
| Achievmnt | x | | x | x | | | | | x | | | |
| Autonomy | x | x | | | x | | x | | | | | |
| Dependence | x | | | | | | | | | | x | x |
| Dominance | | | | | | | | | | | | |
| Change | | | | | x | x | | | x | | | |
| Endurance | x | x | | | x | x | x | | | x | | |
| Aggression | x | x | x | | | | | | | | x | |
| Neuroticsm | | | | | | | | | x | | | x |
| Lie | x | x | | | x | | | x | x | | | |
| Inductive Reasoning | x | | x | | | x | x | | x | | x | |
| Extraversn | x | x | | x | | x | x | x | x | x | | |
| Anxiety | x | x | | x | | x | | x | | x | x | |
| Deference | | | x | x | | x | x | | x | x | | x |
| Order | | x | x | x | | x | x | | x | x | | |
| Exhibition | x | x | | x | | | | | | x | | |
| Affiliatn | | | | x | | x | x | | | | x | x |
| Intraceptn | | | | x | | | | | | x | x | |
| Abasement | | x | | | | x | | x | x | x | | |
| Nurturance | | x | x | | | | | x | x | | | |

TABLE III (continued)

| | GROUP 1 | | | | | | GROUPS 1 & 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable Name | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 |
| Hetero-sexuality | x | | | | x | | x | | x | | | |
| Study Habits | x | x | x | x | | x | x | x | | | | |
| Data Proc. Interest | x | x | x | x | | x | x | x | x | x | | |
| Teaching Interest | | | | | | | | x | | | | |
| Academic Average | x | | | | x | x | x | x | x | | x | |
| Unit Test 1 | NA | NA | x | x | x | | NA | NA | x | x | | |
| Unit Test 2 | NA | NA | NA | x | x | | NA | NA | NA | x | x | x |
| Unit Test 3 | NA | NA | NA | NA | | | NA | NA | NA | NA | x | |
| Unit Test 4 | NA | NA | NA | NA | NA | | NA | NA | NA | NA | NA | x |

these results by depicting the significant variables for each of the six units as determined by the Wherry-Doolittle multiple correlation program, employed upon completion of instruction by Group 1 and again upon completion of instruction by Group 2. As shown in the Table, ten (Unit Five, Group 1) to twenty-one variables (Unit one, Group 1 were listed by the Wherry-Doolittle Program as variables determined to be related to learning in each unit of the data processing course. These lists of variables, and the list of variables determined by the Correlation Coefficient Computation and Test Program to be related to learning in each unit of the course, were combined by the investigator into a list of variables determined by one or both statistical routines to be related to failure in each of the six units of the course as taught by CAI materials. The final lists delineated the variables related to failure and indicated the direction of the relation (as determined by the program which computed and tested correlation coefficients) by stating for each variable whether a high or low measure of the variable was related to a failing unit test score.

The experimenter used the above information on variables related to failure by students in Group 1 (all 115 of whom studied CAI materials) in the process of selecting or constructing alternate materials designed to teach each unit to students in the second instructional group who possessed the characteristics related to failure with CAI materials. Specifically, for each unit the investigator noted the characteristics of students who failed to master the objectives of the unit with CAI materials. The researcher then attempted to determine, using at least some of these characteristics, the features of instructional material which would be suitable for teaching the objectives of that unit to students in subsequent groups who possessed the characteristics related to failure with CAI materials.

The actual process of selecting and constructing alternate materials was begun as soon as a determination was made of the type of instructional material suitable for teaching the objectives of each unit to students possessing the characteristics related to failure in that unit. The experimenter obtained titles of available, commercially produced materials oriented to data processing, using resource guides, lists and reviews published in audio-visual and data processing magazines or in catalogs of instructional materials published by commercial producers. Using the titles and, where available, descriptions and reviews, the investigator obtained copies of thirty-four data processing texts and/or manuals and twenty-eight films or filmstrips thought to be relevant for teaching sets of objectives within the units of the course. The investigator then previewed each text or film or filmstrip in order to judge the appropriateness of the material for teaching. Using an Evaluation Form, the experimenter rated each set of teaching materials and selected from among the available, commercially produced instructional materials those judged to be closely correlated with the curriculum, authentic and accurate, well-organized, of high technical quality and suitable to the demonstrated needs of the students (as indicated by the lists of characteristics related to failure in given units). Of the thirty-four data processing texts and manuals and twenty-eight films or filmstrips previewed, six textbooks and ten films were incorporated into the data processing course. The newly selected materials were then prescribed on an individual basis to students in the second instructional group for whom failure with the CAI material was predicted by the management system.

Where the researcher could find no available commercially produced instructional material designed to teach a particular learning objective or judged to be appropriate for teaching a particular learning objective to students possessing the characteristics related to failure, the investigator constructed instructional material. These constructed materials were incorporated along with the selected (commercially produced) materials. The result of the materials selection and construction procedures was a self-contained (non-CAI) instructional package designed to teach the learning objectives of each of the six units of the data processing course.

### C. EFFECT OF THE COMPUTER MANAGEMENT SYSTEM ON STUDENT PERFORMANCE

The second and final hypothesis of the investigation was concerned with the ability of the computer management system to improve the performance of students in the multi-media data processing course. Specifically, the hypothesis stated:

> The adaptive computer-based management system, whose decision processes are modified on the basis of performance data for all past students as it "learns" about the effects of its decisions, can improve the performance of successive groups of students in a multi-media data processing course: the performance of the second group of pupils will be greater than the first group.

The analysis of the effectiveness of the computer management system was accomplished by performing an analysis of covariance which compared student performance in a computer managed environment (Group 2, N = 119) to student performance in an unmanaged environment (Group 1, N = 115). Specifically, a one-way analysis of covariance adjusted for thirty-three background variables was performed for each of the six unit tests and the final exam. Tests were performed by the researcher to justify the use of the analysis of covariance procedure as a valid technique for comparing the performance of students in a computer managed environment to the performance of students in an unmanaged environment. Specifically, where applicable, statistical tests were employed to ascertain if the data of the investigation satisfied the conditions set forth by Elashoff[38] for correct utilization of the technique. Results of the tests and the procedures for selecting and testing subjects confirmed that the data of the investigation did indeed satisfy the following conditions:

1. random assignment of individuals to treatments;
2. criterion scores have a linear regression on X scores;
3. there is no slope-treatment interaction;
4. criterion scores have a normal distribution; and
5. criterion scores are a linear combination of independent components.

Because the sample sizes for each treatment group in the investigation were approximately equal, a test for the final assumption - that of homogeniety of variances - was not conducted by the researcher. As stated by Elashoff[39] and Scheffé,[40] with approximately equal sample sizes for each treatment, the results of the analysis of covariance will not be effected significantly if the variances are not homogeneous.

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[38] Janet Elashoff, "Analysis of Covariance: A Delicate Instrument," American Educational Research Journal, 6 (May, 1969), 385.

[39] Ibid., p. 395.

[40] Henry Scheffé, The Analysis of Variance (New York: John Wiley and Sons, 1959), p. 83.

The analysis of covariance was employed to insure the statistical equivalence of the two groups in background variables determined to be related to learning in the data processing course. The thirty-three background variables, listed in Table IV, were selected on the basis of results of the Wherry-Doolittle Program obtained with data for Groups 1 and 2, combined.

The effect of the analysis of covariance on the unit test and final exam scores is summarized in Table V, which describes the means of the unit test and final exam scores before and after adjustment through the analysis of covariance. From Table V, the means were adjusted (raised or lowered) at least .6 of a point for Unit Test 1 and at most 3.3 points (for Unit Test 3, Group 1). In short, the effect of controlling through the analysis of covariance for the influence of differences between the two instructional groups in the thirty-three background variables was a total adjustment in mean scores a minimum of .6 of a point and a maximum of 3.3 points.

The application of the analysis of covariance with thirty-three covariates produced F ratios for the between-group source of variance for each of the six unit tests and for the final examination. Table VI presents these F ratios. At the .05 level of significance with 1 and 199 degrees of freedom, the ratios indicated statistically significant differences between the groups for Units Three, Four, Six and for the final examination. From Table V, we see that while the mean of Unit Test 3 for the managed instructional group (Group 2) is less than the respective mean for the unmanaged group (Group 1), the means of Unit Tests 4 and 6 and of the final examination are greater for the managed group (Group 2). We can thus summarize the results of the test of Hypothesis 2 as shown in Table VII. From the Table, the experimental hypothesis that Group 2 > Group 1 is rejected at the .05 level for Unit Three in favor of the alternative hypothesis that Group 2 is not greater than Group 1. Finally, the experimental hypothesis that Group 2 is greater than Group 1 is supported at the .05 level for Units Four and Six and for the final examination. In short, the foregoing analysis rejected for Unit Three but supported for Units Four, Six and for the final examination the hypothesis that the computer management system can improve the performance of a second group of students in a multimedia data processing course.

## V. DISCUSSION, RECOMMENDATIONS AND CONCLUSIONS

In this investigation, a six unit course in the Fundamentals of Data Processing was utilized as the program of instruction through which the effectiveness of the management system was studied. Consequently, the results of the testing of the two experimental hypotheses which are

## TABLE IV

## BACKGROUND VARIABLES USED AS COVARIATES

| VARIABLE NAME |
|---|
| 1. Credits |
| 2. Mother's Education |
| 3. Academic Average |
| 4. Language Aptitude |
| 5. Programming Aptitude |
| 6. Endurance |
| 7. Lie |
| 8. Extraversion |
| 9. Deference |
| 10. Heterosexuality |
| 11. Study Habits |
| 12. Grade Level |
| 13. Sex |
| 14. Age |
| 15. Father's Education |
| 16. IQ |
| 17. Non-Language Aptitude |
| 18. Achievement |
| 19. Autonomy |
| 20. Dependence |
| 21. Dominance |
| 22. Need for Change |
| 23. Aggression |
| 24. Neuroticism |
| 25. Inductive Reasoning |
| 26. Anxiety |
| 27. Need for Order |
| 28. Exhibitionism |
| 29. Affiliation |
| 30. Intraception |
| 31. Abasement |
| 32. Nurturance |
| 33. Mean Income |

## TABLE V

## SUMMARY OF MEANS OF UNIT TEST AND FINAL EXAMINATION SCORES

| Test Name | Means Before Covariance |  | Means After Covariance |  | Difference in Means (After Mean-Before Mean) |  |
|---|---|---|---|---|---|---|
|  | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 |
| Unit Test 1 | 68.4 | 71.6 | 69.0 | 71.0 | +.6 | -.6 |
| Unit Test 2 | 78.9 | 85.6 | 81.3 | 83.3 | +2.4 | -2.3 |
| Unit Test 3 | 71.6 | 72.3 | 74.9 | 69.2 | +3.3 | -3.1 |
| Unit Test 4 | 76.6 | 91.9 | 78.3 | 90.2 | +1.7 | -1.7 |
| Unit Test 5 | 65.1 | 57.9 | 62.0 | 60.8 | -3.1 | +2.9 |
| Unit Test 6 | 77.3 | 94.7 | 75.9 | 95.9 | -1.4 | +1.2 |
| Final Exam | 51.4 | 71.6 | 52.9 | 70.2 | +1.5 | -1.4 |

## TABLE VI

## F RATIOS BETWEEN GROUP VARIANCES FOR EXAMINATIONS

| Examination Name | df | Mean Square | F | Level of Significance |
|---|---|---|---|---|
| Unit Test 1 | 1 & 199 | 139.994 | .628 | .429 |
| Unit Test 2 | 1 & 199 | 140.044 | .645 | .423 |
| Unit Test 3 | 1 & 199 | 1125.829 | 4.346 | .038 |
| Unit Test 4 | 1 & 199 | 4824.049 | 27.630 | .001 |
| Unit Test 5 | 1 & 199 | 55.451 | .075 | .784 |
| Unit Test 6 | 1 & 199 | 13640.436 | 85.527 | .001 |
| Final Exam | 1 & 199 | 10177.056 | 54.784 | .001 |

## TABLE VII

## SUMMARY OF RESULTS OF TESTING HYPOTHESIS 2. $\alpha = .05$

| TEST VARIABLE NAME | HYPOTHESIS RESULT |
|---|---|
| Unit Test 1 | Group 2 = Group 1 |
| Unit Test 2 | Group 2 = Group 1 |
| Unit Test 3 | Group 2 ≠ Group 1 |
| Unit Test 4 | Group 2 > Group 1 |
| Unit Test 5 | Group 2 = Group 1 |
| Unit Test 6 | Group 2 > Group 1 |
| Final Examination | Group 2 > Group 1 |

presented in this document pertain to that course of instruction. For this reason, before discussing the results of the experiment, it is important to discuss the generalizability of the results to courses of instruction other than the Fundamentals of Data Processing program and to learner variables which may pertain to other courses of instruction.

The computer management system implemented and tested in this investigation was designed as a generalized system which can be applied to a course of instruction at elementary, secondary or higher education levels provided that the course meets the following criteria:

1. A set of measurable behavioral objectives is defined by the course designer, instructor or researcher;

2. A set of instructional materials exists to teach the behavioral objectives of the course; and

3. A set of objective, reliable examinations exists to assess mastery of the objectives of the course.

Note that there are no restrictions on the instructional media utilized in the course or on the modality of instruction. The computer management system can be applied to a course taught in a large group or small group as well as to a course taught in the independent study mode employed in this investigation. Similarly, the management system was designed to permit an instructor for, or researcher with, a computer-managed course to employ any combination of educational media including the classroom lecturer or teacher in order to effect the learning objectives of the course. There are no restrictions to the CAI, print, film and audio tape media utilized in the course of instruction of this study. Finally, while the set of learner characteristics included in this investigation was limited to those (enumerated in Table I) which, it was thought, might be related to success or failure in a data processing course, the computer management system was designed as an open-ended system which can include an indefinite number of variables thought to be related to learning in a given course of instruction. The only qualifications for learner characteristics included in the computer management system are the following:

1. the variable must be quantifiable; and

2. reliable and valid instruments must exist to measure the characteristic.

In short, the generalized nature of the design of the management system indicates that the findings of this investigation can be generalized to courses of instruction for which behavioral objectives have been defined, appropriate instructional materials have been selected and reliable measuring instruments have been designed. Further, the nature of the design of the system suggests that the findings can be generalized to learner variables which can be quantified and reliably and validly measured. With this is mind, a discussion and evaluation of the results of the two experimental hypotheses and the implications of these results follows.

The first hypothesis tested in the investigation stated that the computer management system could isolate from a specified list of characteristics those learner characteristics which are related to success and failure in given instructional segments of the data processing course as taught by specified instructional materials. As presented in Table II, the computer management system was able to identify, upon completion of instruction by the first group of students, nine, fourteen, twelve, nine, fifteen and twelve variables which were related to learning in Units One through Six, respectively, as taught by CAI materials. Similarly, the Table shows that upon completion of instruction by the second group, the computer management system was able to identify ten, sixteen, eighteen, twenty-two, sixteen and fourteen variables which were related to learning in Units One through Six of the course as taught by CAI materials. These results support the hypothesis that the computer management system can identify the characteristics related to success and failure in segments of the data processing course as taught by specified instructional materials.

It must be mentioned, however, that due to a large sample size in each treatment group, the correlation coefficients of the variables determined (by the method described above) to be related to learning in the data processing course were small (low magnitude). Further, the coefficients of determination ($r^2$) for these variables, which describe the amount of variance explained by the correlation of a variable with a unit test score, were correspondingly low. Finally, referring to Group 1 data in Table II, we find that of the twenty-nine variables tested for relation to learning in the course, only thirteen were found to be related to learning in at least three of the six units. This finding indicates a lack of consistency in correlation with unit test scores for each of the remaining sixteen variables. The low magnitude of correlation coefficients of variables determined to be related to learning in the course, and the lack of consistency in correlation with unit test scores for about half of the variables tested for relation, suggest that future research designed to identify still other learner characteristics or background variables related to learning would be valuable. (See Recommendation 1.) Such research might identify variables which yield (1) higher correlations with unit test scores and/or (2) greater consistency in correlation across units, thereby adding even stronger support of the hypothesis that the computer management system can identify the characteristics related to success and failure in segments of the course as taught by specified instructional materials.

The researcher points out that the identification of variables related to learning that was effected in the present investigation (through the Correlation Coefficient Computation and Testing Program, the Wherry-Doolittle Program and also the Background Data Classification Program) enabled the investigator to examine in depth the relationship between previous unit test scores and such variables as IQ, programming, language and non-language aptitude, need for achievement, academic average, study habits, interest in data processing and inductive reasoning ability. This identification of significant variables for each unit provided descriptions of the types of students who failed with CAI materials. These descriptions were in turn applied to the selection and construction of alternate instructional materials. The value of such identification of variables related to failure is particularly apparent from the finding that for one unit (Unit Five), it is the students with high IQ scores, high language and non-language aptitude scores, high programming aptitude scores, high inductive reasoning scores, good study habits, high academic averages and high scores in three previous unit tests who are failing to master the objectives of a unit. Clearly, an instructor would not expect such a finding. More important, the instructor who does not have (or have access to) the data collection and analysis capabilities of the computer-based management of this investigation lacks the mechanism for making such a determination empirically. Thus, one can see the value in the finding that the computer system can identify the characteristics related to learning with given instructional materials of a specified course of instruction. While such identification cannot, of course, guarantee that in applying the results, the researcher or instructor will infallibly select appropriate and effective alternate materials, it does identify a potential problem and provide valuable, meaningful data that might indicate the types of material appropriate for teaching students who fail with existing materials.

The first hypothesis was concerned with the identification of characteristics related to success and failure in each unit as taught by both the CAI and by the non-CAI materials utilized in the study. As previously stated, however, the non-CAI materials were employed as primary instructional materials in only two units of the course and by too few students in each of these units to permit the identification of characteristics related to success and failure with these alternate materials. The lack of ability, at this time, to make meaningful determinations of the characteristics related to learning with the non-CAI materials suggests another future research endeavor. The utilization in a controlled research study of the non-CAI materials by a group of at least fifty students would be a valuable continuation of the current study. (See Recommendation 2.) Conclusion of the research would permit both the identification of the characteristics related to success and failure with non-CAI materials, and the determination of a set of regression equations which would generate for each student a set of predicted unit test scores given non-CAI materials of instruction. In short, such a controlled research study would add to the predictive ability of the computer management system. Further, it would provide empirical data attesting to the need to revise and extend the non-CAI materials. Finally, it would extend the test of the ability of the computer management system to identify the characteristics relating to learning with a second set of instructional materials for the data processing course.

Still another research study pertaining to the ability of the computer management system to identify variables related to learning in a course of instruction is indicated by the results of the Wherry-Doolittle Program. In order to interpret the statistical significance of obtained correlations, the experimenter studied the coefficients of determination ($r^2$) computed by the Wherry-Doolittle Program by squaring each multiple correlation coefficient generated by the program. In so doing, the investigator noted that coefficients of determination (which describe the amount of variance explained by the correlation of the background variables with unit test scores) were greater for each of the unit tests upon completion of instruction by Group 1 than upon completion of instruction by Group 2. Specifically, for each unit there was a reduction in the multiple correlation coefficients which in turn resulted in a reduction in the coefficients of determination for each unit. The explanation for the decrement lies in the fact that in the second instructional group, only those students who possessed the learning characteristics related to success with CAI materials were permitted to utilize those materials. This limitation resulted in a decrease, after the second instructional group, in the range of measures of each background variable which in turn lowered the correlation coefficients. Because in further research with the management system applied to the data processing course, there will still be restrictions on the utilization of CAI materials and consequent decreases in multiple correlation coefficients, the researcher suggests still another relevant extension of the present investigation. (See Recommendation 3.) This future research project should be directed to the investigation of new, additional learner characteristics which may be determined to be related to learning on the data processing course as taught by CAI materials. The intent of such an investigation would be to yield larger multiple correlation coefficients and coefficients of determination, thereby increasing rather than decreasing the existing predictive ability of the computer management system.

Attention is now given the second experimental hypothesis, which stated that the adaptive computer-based management system, whose decision processes are modified on the basis of performance data for all past students as it learns about the effects of its decisions, can improve the performance of successive groups of students in a multimedia data processing course: the performance of the second group of students will be greater than that of the first group. The results of testing this hypothesis are summarized as follows:

1. The experimental hypothesis that Group 2 > Group 1 failed to be confirmed at the .05 level for Units One, Two and Five;

2. The experimental hypothesis that Group 2 > Group 1 was rejected at the .05 level for Unit Three in favor of the alternative hypothesis that Group 2 is not greater than Group 1; and

3. The experimental hypothesis that Group 2 > Group 1 was supported at the .05 level for Units Four, Six and for the final examination.

A discussion of these findings follows. However, it is useful first to restate the characteristics of the computer management system employed with the second instructional group, for the effectiveness of any or all of these components explains the experimental findings.

The computer management system of this investigation utilized data obtained with students in the first instructional group to generate for each unit a regression equation which was used to predict for each student a score on each unit test given CAI materials. When a score of less than sixty percent on a unit test was obtained for a student, alternate, non-CAI, materials were prescribed by the management system and studied exclusively by the student for that unit. A second characteristic of the management system was the day-to-day monitoring of the progress of the student and the use of the daily performance records to prescribe portions of the same non-CAI materials for remediation. Specifically, the computer system prescribed remedial materials to any student who failed to answer correctly fifty percent of the questions presented in the course of instruction for a unit which pertained to a specified set of learning objectives for that unit. In short, the employment of predictive equations, the utilization of non-CAI instructional materials and the prescription to failing students before a unit test of non-CAI remedial materials distinguished instruction for the second group under the management system. With this in mind, an in-depth examination of the results of the test of Hypothesis 2 follows.

First, referring to Units One and Two one notes that the results failed at the .05 level to confirm the experimental hypothesis that Group 2 is greater than Group 1. This failure to support the experimental hypothesis can be attributed to the lack of usage on a widespread basis of non-CAI materials. All of the 119 students in Group 2 were assigned on the basis of predicted unit test scores to study CAI material as the primary instructional resource for Unit One. Further, the non-CAI materials for Unit One were prescribed as remedial materials for Objectives A, B, C, D, E and F to only four, five, two, five, eight and no students, respectively, of the 119 pupils in Group 2.

The data for Unit Two are similar. All of the 119 students in Group 2 were assigned to study CAI materials as the primary instructional resource for Unit Two. Further, non-CAI materials for Unit Two were prescribed as remedial materials for Objectives A, B, C, D and E, and F to only four, six, three, four and two students, respectively.

The investigator concludes from these figures that failure to prescribe the non-CAI materials as remedial materials to a larger number of students resulted in a failure to obtain statistically significant differences between the groups for Units One and Two. On the basis of these conclusions, the investigator makes a recommendation for further research. The failure to prescribe non-CAI materials as remedial materials to more than ten percent of the students in Group 2 for Units One and Two suggests to the investigator the need to raise the cut-off score for prescription of remedial work. As experimental data indicate that a cut-off score of fifty percent is too low to be effective, the author suggests the use of a cut-off score of sixty, seventy, or seventy-five percent. Use of a higher cut-off would lead to the prescription of remedial work to a larger number of students, thereby fostering greater variation between the managed and unmanaged treatment groups and providing a greater test of the effectiveness of the computer management system.

Referring now to Unit Three, one notes that the experimental hypothesis was rejected at the .05 level in favor of the hypothesis that Group 2 is not greater than Group 1. The explanation of these findings is found by referring to two facets of instruction under the management system. First, the direction of the differences coupled with a standard error of measurement of 13.7 for predicted Unit Test 3 scores emphasize that the ability of the computer management system to assign appropriate primary instructional materials on the basis of the existing predictive equations was weak. Again, the need is indicated to investigate in future research variables which can improve the predictive ability of the management system. Second, while all 119 students in Group 2 studied CAI materials for Unit Three, the non-CAI materials for this unit were used as remedial materials for Objectives A and B, C, D, E and F by twenty, thirteen, twenty-one, fourteen and twelve students, respectively. Despite the widespread use of the non-CAI materials, there was still a failure to obtain improved unit test scores. Use of these remedial materials by at least ten percent of the students in Group 2 coupled with lower unit test scores indicates a failure on the part of the non-CAI materials to remediate learning deficiencies and to effect the learning objectives of the unit. The investigator recommends, therefore, that future research involving the computer management system be preceded by research designed to verify the ability of selected instructional materials to effect the objectives of the course of instruction. While such an investigation was precluded by the rigid time constraints of the present investigation, the need is indicated to study empirically, in future research, the effectiveness of alternate instructional materials prior to utilization of those materials in a complete run. (See Recommendation 4.)

Finally, the author points out that while the findings with respect to Unit Three failed to support the experimental hypothesis of learning gains for the computer managed group, the results did demonstrate the valuable ability of the management system to indicate to the researcher the need for the revision of instructional materials. (See Recommendation 6.) This capability, evidenced in the present investigation, is most necessary.

Referring now to Unit Four, one notes that the experimental hypothesis that Group 2 > Group 1 was confirmed at the .001 level. Since no student was assigned to study non-CAI materials as the primary instructional resource for the unit, the explanation for the findings lies in the ability of the non-CAI materials to remediate learning difficulties and to effect the learning objectives of Unit Four. Non-CAI materials for the unit were used as remedial studies for Objectives A, B, C, D and E, F and G by fifteen, eleven, twenty-eight, thirteen, eighteen and ten students, respectively. Since these numbers represent nearly ten to twenty-five percent of the students in Group 2, the investigator concludes that the significant gains in learning must be attributed to the frequent utilization of remedial materials and to the effectiveness of these resources when utilized.

Our attention turns now to Unit Five, where the experimental hypothesis that Group 2 > Group 1 failed to be confirmed at the .05 level. There are two logical explanations for this failure. One is the quality of the predictions made by the system. The standard error of measurement for predicted Unit Test 5 scores was a very high 22.40, meaning that the extent of error in an obtained predicted score was greater than ±22 points. Clearly, with a standard error of this magnitude, the quality of the decisions made on the basis of predicted scores is poor, and study of CAI or non-CAI materials by given students because of these decisions may have been inappropriate. Thus, once again, the need to improve the predictive ability of the management system is evidenced.

The second explanation for the failure to obtain improved performance with the managed group is the quality of the non-CAI materials. Eleven students were assigned to study non-CAI materials as the primary instructional resource for the unit. The mean unit test score obtained by these students was 58.3, which is below the passing mean score of sixty. Further, the non-CAI materials were employed in remedial study for Objectives A, B, C and D by fifteen, thirty-four, fourteen and twenty-five students, respectively, of the 108 students in Group 2 who utilized the CAI materials. The failure to obtain improved performance with the managed instructional group despite the widespread utilization of the non-CAI materials attests to the poor quality of these resources and the need to revise the alternate instructional materials for Unit Five. (See Recommendation 6.) Once again the computer system points out the need to revise instructional materials forcing the investigator to conclude for a second time that there is a need to test empirically, prior to use in a complete run, the effectiveness of alternate instructional resources.

Referring now to Unit Six, one notes that the experimental hypothesis that Group 2 > Group 1 was confirmed at the .001 level. Here, as with Unit Four, the explanation for the findings lies in the ability of the non-CAI materials to effect the learning objectives of the unit and to remediate learning difficulties. Non-CAI materials were prescribed as primary instructional resources for six students; the mean unit test score obtained by these students was 93, indicating that the non-CAI materials were capable of effecting the learning objectives of the unit. Further, the non-CAI materials for Unit Six were used in remedial study of Objective A and Objectives B and C by twelve and sixteen students, respectively - or ten to fifteen percent of the 113 students in Group 2 who studied Unit Six via CAI. The investigator concludes from the above data that gains in learning must be attributed to the utilization of effective non-CAI materials.

Finally, with respect to the final examination, the experimental hypothesis was confirmed at the .001 level. This finding results from the fact that gains in learning were effected in four of the six units of the course. Specifically, gains of 2 points, 3 points, 11.8 points and 20 points were achieved by the computer-managed group on Unit Tests 1, 2, 4 and 6, respectively. Further, a gain of 17.8 points was achieved by the computer-managed group on the final examination which was designed to measure mastery of the objectives of the entire course. The researcher concludes from these data that the changes in performance effected by the management system in the individual units of the course combined to produce a significant improvement in learning in the course as a whole. In short, a significant improvement in learning in the data processing course as a whole was effected after just one pass through the course under the management system. This finding suggests to the author that further applications of the system to several successive groups, utilizing the cumulative data obtained from each additional pass through the course, should be undertaken to determine the limit of learning gains. The upper bound on the effectiveness of the computer management system has yet to be determined, and should be investigated in future research. (See Recommendation 7.)

## CONCLUSIONS

Based upon the discussion and data presented above, the investigator presents the following conclusions:

1. The findings of this study may be applied to a population represented by the population of this investigation who are studying a course of instruction for which behavioral objectives have been defined, appropriate instructional materials have been selected and reliable measuring instruments have been designed.

2. The findings of this study may be generalized to learner variables which can be quantified and reliably and validly measured.

3. Upon completion of instruction by the first group and again by the second group, the computer management system was capable of isolating from a specified list of characteristics, those characteristics related to success and failure in each of the six units of the data processing course as taught by CAI materials.

4. No significant differences in learning were found in three of the six units of the course; in one of the six units, the computer management system was not capable of effecting a learning gain; in the two remaining units and for the final examination, the computer management system was capable of effecting large, significant learning gains.

5. The computer management system was able to indicate the need for the revision of some of the instructional materials of the course.

## RECOMMENDATIONS

Finally, the data resulting from tests of the two experimental hypotheses provided the basis upon which the researcher is able to make the following recommendations:

1. That future research with the computer management system be directed to the identification of additional learner characteristics or background variables which yield (1) higher correlations with unit test scores and/or (2) greater consistency in correlation across units. The intent of such research would be to add strong support of the hypothesis that the computer management system can identify the characteristics related to success and failure in segments of the data processing course as taught by specified instructional materials.

2. That future research be directed to the determination, with a large population sample, of the ability of the computer management system to isolate the characteristics related to success and failure with the effective non-CAI materials of the data processing course - those for Units One, Two, Four and Six. Included should be an

effort to employ on a wider scale the non-CAI materials with a population of students who possess the characteristics related to failure with the CAI resources of the course. The intent of this research would be to provide a second set of regression equations and to provide data which can be employed in the construction of a third instructional path.

3. That future research be concerned with the improvement of the predictive ability of the computer management system. These efforts should concentrate on the identification of additional learner variables related to success and failure in the given units of the data processing course. The intent of this research would be to increase the multiple correlation of background variables with unit test scores, and to decrease the standard error of measurement of predicted unit test scores, thereby improving the quality of decisions based on these predicted scores.

4. That future research with the computer management system investigate the effects of employing cut-off scores of higher than fifty percent for the prescription of remedial material. The intent of this research would be to determine whether increased remediation will lead to greater improvements in learning as reflected by unit test scores.

5. That future research with the computer management system be preceded by studies designed to verify empirically, before usage in a complete run, the ability of the instructional materials of the course to teach learning objectives of the program of instruction. The intent of this research would be to avoid the utilization of teaching material incapable of effecting the objectives of a unit.

6. That the non-CAI materials for Units Three and Five, which failed to teach the objectives of their respective units, be revised.

7. That future research extend the current investigation to additional successive instructional groups. The intent of such research should be so designed as to determine the extent to which gains in learning can be effected in a course

of instruction by repeated applications of a computer management system which "learns" from its previous decisions.

8. That future research extend the application of AIMS to additional courses offered at differing grade levels, thus extending the investigation of the ability of the system to improve instruction through the individualization of instruction.

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# 8

# PROGRAMMED MATHEMATICS CONTINUUM

*A model computer managed, self-paced, and individualized course of instruction in Elementary Algebra.*

# THE PROGRAMMED MATHEMATICS CONTINUUM

## Table of Contents

I. STATUS ........................................... 1

II. DESCRIPTION ...................................... 1

- A. Purpose ........................................ 1
- B. Scope .......................................... 1
- C. Instructional Modes ............................ 2
- D. Self-Pacing .................................... 2
- E. Individualization .............................. 2
- F. Computer Interface ............................. 2
- G. Computer Articulation .......................... 3
- H. Criterion Checks ............................... 5
- I. Remediation .................................... 7
- J. Optimization ................................... 9

III. EVALUATION ......................................12

IV. SUPPORT MATERIAL .................................15

- A. Software .......................................15
- B. The Handbook ...................................17

V. UTILIZATION OF THE SYSTEMS ANALYSIS APPROACH ........19

VI. THE DEVELOPMENT OF THE PMC SYLLABUS ...............22

VII. EVOLUTION OF THE MBO LIST .......................27

- A. Original Terminal Objectives ...................27
- B. A Structured List of Objectives ................27
- C. Combined Listing ...............................29
- D. Revised and Enlarged MBO List ..................31
- E. Concept Catalog ................................32

VIII. HISTORY AND OPERATIONAL EXPERIENCE .............33

- A. Development of the Preliminary Computer Program Title: VICAR (Variable Input Computer Assembled Records)........................33
- B. Installation and Replication Experience .........34
- C. Conclusions Derived from the Several Course Operations ..............................39
- D. Development of the SIM/AIMS Mode ...............41

GLOSSARY ..............................................47

FLOWCHARTS EXPLAINING THE SIMS/AIMS MODE OF COURSE OPERATION ...................................52

PROGRAMMED MATHEMATICS CONTINUUM

Table of Figures

FIGURE 1 ....................................4

FIGURE 2 ....................................6

FIGURE 3 - Question File ....................7

FIGURE 4 - Post Test ........................8

FIGURE 5 - Student TO Performance ...........9

FIGURE 6 - Class TO Performance .............9

FIGURE 7 ....................................10

FIGURE 8 ....................................11

FIGURE 9 ....................................13

FIGURE 10 ...................................16

FIGURE 11 ...................................17

FIGURE 12 ...................................26

FIGURE 13 - Original Objectives ............28

FIGURE 14 - Structured List Objectives ....................29

FIGURE 15 - Original Structure-Algebraic Concepts ............30

FIGURE 16 - Objectives, Combined Listing .......................31

FIGURE 17 - Control Sheet ..................44

LEGEND ......................................52

ABSTRACTED FLOW CHART ......................53

PRE-TEST ROUTINE ............................54

STUDY GUIDE ROUTINE .........................55

REMEDIAL INSTRUCTION REFERRAL ROUTINE ...................................56

SUPPLEMENTARY INDIVIDUAL INSTRUCTION ROUTINE ..............................57

END-VOLUME ROUTINE .........................58

POST TEST PRESCRIPTION ROUTINE .............59

RE-TEST ROUTINE ............................60

GUIDANCE REFERRAL ROUTINE ..................61

# THE PROGRAMMED MATHEMATICS CONTINUUM

## I. STATUS

The Programmed Mathematics Continuum (PMC) meets the specifications as outlined in the broad objectives of the Research Project.

a. The PMC has been organized, developed and refined as a computer monitored system through application of the Systems Analysis technique.

b. It is operational having been installed on both campuses of the New York Institute of Technology during the validation period.

c. It has been installed in several off-campus environments demonstrating its replicability and adaptability. This is a continuing and expanding activity.

d. It is structured to accommodate an individualized, self-paced mode of instruction enhanced by a thorough statistical analysis of student performance. This analysis is also applied to optimization of the course.

e. The accounts of the project have been, and are continuing to be, widely disseminated with constant demonstrations of its operation.

## II. DESCRIPTION

### A. PURPOSE

The PMC Level I is an original course, cast in the branching programmed mode, designed to teach, test and guide the student in the study of Elementary Algebra while each response is monitored and analyzed by the Computer Management System (AIMS III).

### B. SCOPE

The syllabus follows the guidelines of the Curriculum Development Committee of the High School Division of the Board of Education of the City of New York and follows the leadership in the field of mathematics education furnished by the New York State Board of Regents and the School Mathematics Study Group.

1. A review of the development of the PMC syllabus is presented in Section VI of this chapter.

2. PMC Level I is a full year course in Elementary Algebra. It is appropriate not only for the first year of high school mathematics but it is also suitable for use as a remedial course in the Special Education Departments of two year colleges and technical schools.

## C. INSTRUCTIONAL MODES

The material is divided into 18 major units called Volumes. Each volume is subdivided into five segments. The monitoring capabilities of the computer for record keeping and analysis permit this course to be presented by several different administrative methods.

It can be adapted for use as:

1. a self-study program;

2. an individually self-paced course with teacher guidance while in a classroom group situation; and

3. a regulated paced program under teacher direction using the PMC as a workbook activity paralleling other class instruction.

## D. SELF-PACING

It is possible for individual students or several different groups of students to be in different segments of the course at the same time. The monitoring system has been programmed to handle the input materials on an individual basis with summaries of class activities made whenever required.

## E. INDIVIDUALIZATION

Individualized instruction is also achieved through the employment of multiple choice questions in the Study Guide. Each response by the student leads to either a demonstration of the correct solution followed by the next question, or a relevant remedial instruction followed by the direction to loop back to the same question.

## F. COMPUTER INTERFACE

The use of scrambled pagination in the Study Guide requires the student to record his answer choices on a response device that reveals the assigned page relating to each response. At the same time it serves as the computer interface permitting acceptance of the data for analysis of individual and group performance.

1. The original response device consisted of a punch-card which was inserted in a special holder. As the student made his selection of the available multiple choice answers by punching the card with a special stylus, a light would appear through an otherwise opaque matrix revealing the "go to" page number. (A complete description of this process is found in the Instructor's Handbook on pages 82 and 83.)

2. This assembly has been replaced by a latent image sheet (see Fig. 1). The student indicates his answer choice by marking the appropriate square with a felt pen containing a special fluid. The pen leaves an indelible mark and at the same time causes a latent image of the "go to" page number to appear. A pencil mark made by the student under the choice permits the sheet to be scanned as a computer interface.

### G. COMPUTER ARTICULATION

Computer analysis of each student's response is possible through the assignment of a detailed coding system that relates each question in the Study Guide, homework and testing program to a specific measurable behavioral objective, and each erroneous answer choice to a Concept Catalog number.

1. A measurable behavioral objective (MBO) is a statement of a specific concept or skill that is to be learned by a student and the conditions under which his ability to demonstrate his knowledge is to be tested.

    a. Major objectives are designed as terminal objectives (TO). Single-concept objectives that lead to each terminal objective are called enabling objectives (EO). The TOs and EOs together make up the list of MBOs.

    b. For ease of reference and analysis by the computer monitoring system, each MBO has been given a five digit code

PMC LEVEL 1
VOL 6 SEG 2

SOCIAL SECURITY NO

COMPLETION TIME
HRS. MIN

VOLUME SEGMENT

COURSE NUMBER

PAGE NO.

**NEW YORK INSTITUTE of TECHNOLOGY**

EDUMATOR®

STUDENT NAME

DATE

FORM 1

|  | A | B | C | D |
|---|---|---|---|---|
| 1 |  |  | 53<br>1 |  |
| 2 | 35<br>2 | 45<br>1 | 40<br>2 |  |
| 3 |  |  | 56<br>1 |  |
| 4 |  | 62<br>1 |  | 52<br>1 |
| 5 |  |  | 51<br>1 |  |
| 6 |  | 72<br>1 |  |  |
| 7 | 43<br>2 | 50<br>2 | 60<br>1 |  |
| 8 | 70<br>1 |  |  |  |
| 9 |  |  | 77<br>1 |  |
| 10 | 57<br>2 | 68<br>1 |  |  |
| 11 |  |  | 61<br>2 |  |
| 12 |  |  | 73<br>1 |  |

|  | A | B | C | D |
|---|---|---|---|---|
| 13 |  |  |  | 80<br>1 |
| 14 |  |  | 71<br>1 |  |
| 15 | 82<br>1 | 66<br>2 |  |  |
| 16 | 87<br>1 |  |  |  |
| 17 |  |  |  | 78<br>1 |
| 18 |  |  |  | 84<br>1 |
| 19 |  |  | 90<br>1 |  |
| 20 |  |  |  |  |
| 21 |  |  |  |  |
| 22 |  |  |  |  |
| 23 |  |  |  |  |
| 24 |  |  |  |  |

PMC Fig. 1

number. For example, consider

| | |
|---|---|
| MBO number | 1 8 3 2 1 |
| which represents | 18 3 2 1 |
| | VOL 18 SEG 3 TO 2 EO 1 |

2. The Concept Catalog is a coded listing of concepts and skills. It is used to indicate the most likely error that a student made in answering a question. It is distinct from the MBO to which the question is related.

3. A demonstration of the development of the Concept Catalog and the final MBO List is presented in Section VII of this chapter.

4. The list of measurable behavioral objectives and the Concept Catalog have been compiled and placed in one Volume.

### H. CRITERION CHECKS

The testing program associated with the PMC includes a Test A and a Test B for each Study Guide volume as well as a midterm examination (in two forms) and a final examination (also in two forms).

1. Since the questions and the designated correct answers have been examined by the writing team for validity, it is assumed that a correct answer indicates mastery of the MBO associated with that question.

2. A compilation of all the correlations between the questions and the MBOs as created by the course writers is presented in the MBO Cross Reference Sheet. A complete set of these can be found in the software file. An excerpt from this list is shown in Figure 2. This is an excerpt from the measurable behavioral objective Cross Reference Sheet that accompanies each Study Guide volume. Each Study Guide question, homework assignment question, pretest criterion check, and posttest criterion check is correlated with an ordered listing of the MBO code numbers, and the Concept Catalog. As noted earlier, the statement of each MBO and each Concept Catalog is found in the bound volume "MBO LIST."

MBO STRATEGY AND CROSS REFERENCE SHEET

VOLUME 2

|  |  |  | QUESTION NUMBER: |  |  |
|---|---|---|---|---|---|
| MBO NUMBER: | CATALOG NUMBER | S.G. | H.W. | TEST A | TEST B |
| 02110 | 1069 | 1,2 | 1 |  |  |
| 02111 | 1069 | 3,4,5 | 1 |  |  |
| 02112 | 3031 | 6,7 | 1 |  |  |
| 02120 | 3031 | 8,9,13,14 | 2 | 1 | 2 |
| 02130 | 2007 | 15,16,17 | 3 | 2 |  |

Fig. 2

3. The computer maintains a file containing similar information. However, it is ordered by question number rather than by MBO number. This file, called the Question File, is the master key for selection of printout information to be supplied to the user as dictated by the nature of the answer choice. An excerpt from this file is presented in Fig. 3. The headings from left to right are interpreted as follows:

"LESS" is the volume number;
"SEG" is the segment number;
"TP" is the type work: 1 is Test B; 2 is Test A; 4 is Study Guide;
"QST" is the question number;
"TO" is the terminal objective code;
"EO" is the enabling objective code;
"CORRECT ANSWER" is just that;
"SKL 1" is the Level of Difficulty.

The second line and the remaining alternating lines show the MBO number, a description of the concept, or the number of the Concept Catalog (the error) and, in the case of a Test A, a remedial textbook prescription.

```
            ***  AIMS MBO LISTING  ***
                 REPORT NUMBER  5

LESS   SEG   TP    QST    TO    EO    CORRECT     SKL
                                      ANSWER       1
-------------------------------------------------------------------
 5      1     2      9    53    30      B          4
05530  SOLUTION OF INEQUALITY                     6014    199/37,40,46,52
 5      1     2     10    53    30      C          4
05530  SOLUTION OF INEQUALITY                     6014    199/53,55,58,66
 5      5     4     15    53    30      C          4
55530    5036    5036    *    6104
 5      5     4     13    53    31      C          4
05531    6009    6009    *    5043
 5      5     4     14    53    31      D          4
```

Question File

Fig. 3

4. Test B may be used as a screening device (pretest) for permitting students with previous exposure to the subject matter to be exempted from the remaining materials in that volume.

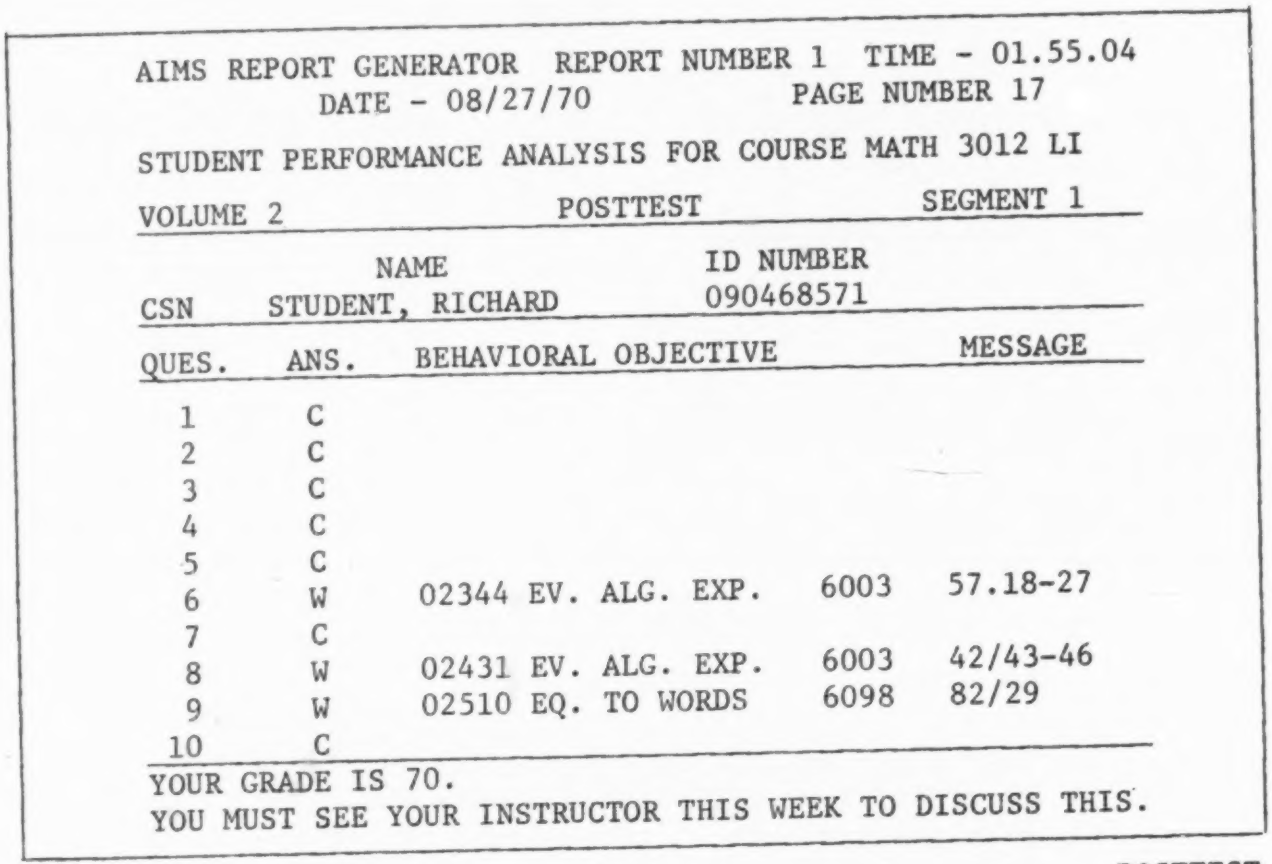
5. Test B can be used as a basis for determining learning increment as evidenced by performance on Test A (posttest) subsequent to the study of the volume.

6. For students who have no previous experience in the subject, Test B may be used as a retest after the remedial work following the posttest has been completed.

## I. REMEDIATION

1. Associated with the posttest and the midterm examination is a set of specific remedial prescriptions that are assigned for additional work when student performance has indicated the need for further instruction.

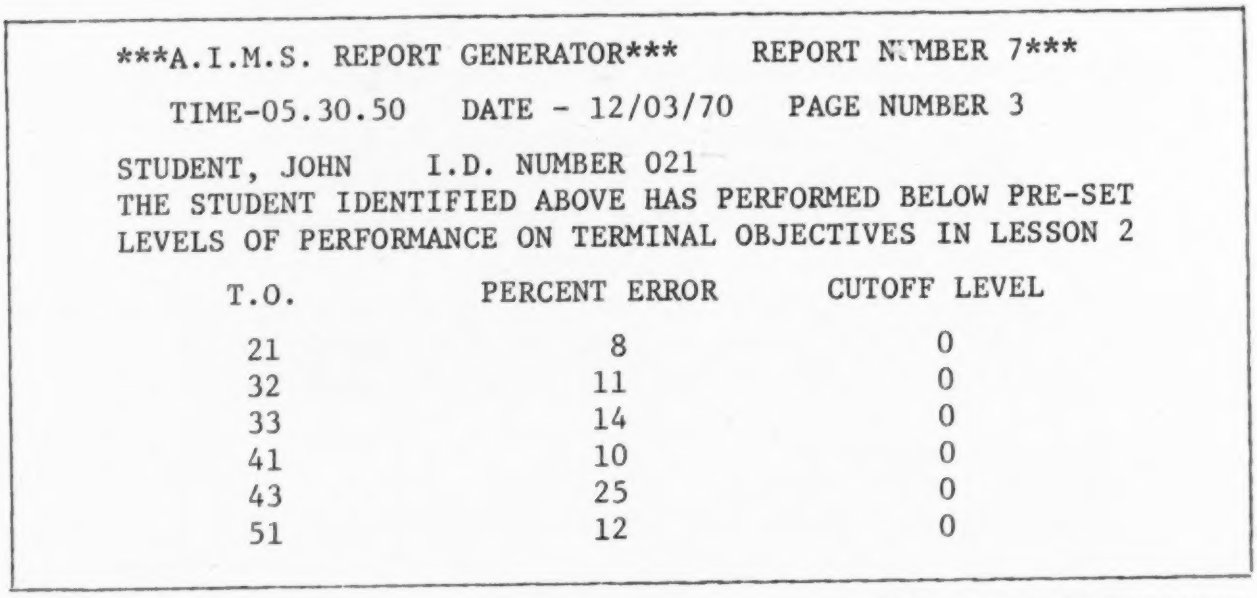
2. These prescriptions are contained in the Question File (Fig. 3). When the computer grades a test, the remedial prescription is included as part of the printout (see Fig. 4).



```
AIMS REPORT GENERATOR  REPORT NUMBER 1  TIME - 01.55.04
           DATE - 08/27/70          PAGE NUMBER 17

STUDENT PERFORMANCE ANALYSIS FOR COURSE MATH 3012 LI

VOLUME 2                POSTTEST              SEGMENT 1
________________________________________________________

               NAME                 ID NUMBER
CSN     STUDENT, RICHARD            090468571
________________________________________________________
QUES.   ANS.   BEHAVIORAL OBJECTIVE               MESSAGE
________________________________________________________
  1      C
  2      C
  3      C
  4      C
  5      C
  6      W     02344 EV. ALG. EXP.     6003     57.18-27
  7      C
  8      W     02431 EV. ALG. EXP.     6003     42/43-46
  9      W     02510 EQ. TO WORDS      6098     82/29
 10      C
________________________________________________________
YOUR GRADE IS 70.
YOU MUST SEE YOUR INSTRUCTOR THIS WEEK TO DISCUSS THIS.
```

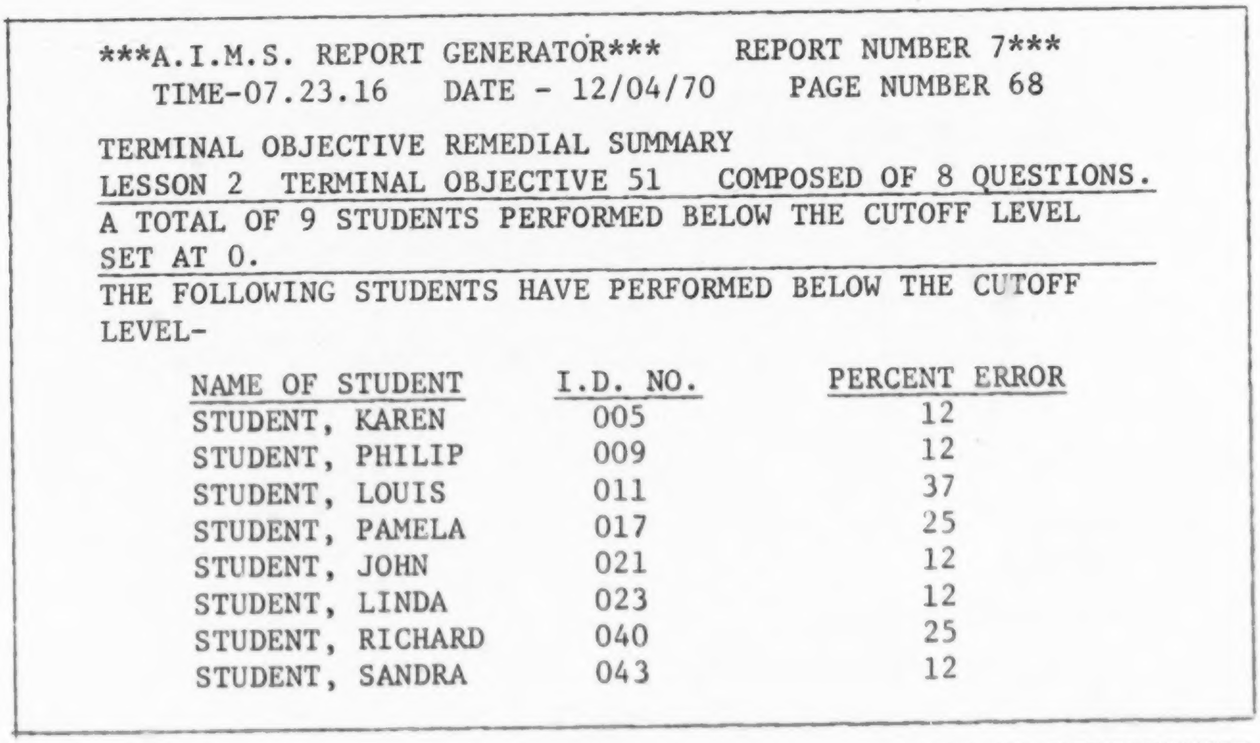
REPORT # 1 Fig. 4 POSTTEST

3. The number of incorrect responses to the Study Guide and test questions are recorded. These are then presented to the instructor in two useful printouts. (See Fig. 5 and Fig. 6.) The report shown in Fig. 5 advises the instructor of the percent error in the individual student's performance on the terminal objectives in the Study Guide, instructional program and testing program. This forms the base for an individual tutoring session. The report shown in Fig. 6 presents a list of students who have failed to meet the requirements relating to a specific terminal objective. This forms the nucleus for a group remedial session.



```
***A.I.M.S. REPORT GENERATOR***     REPORT NUMBER 7***
   TIME-05.30.50   DATE - 12/03/70   PAGE NUMBER 3

STUDENT, JOHN    I.D. NUMBER 021
THE STUDENT IDENTIFIED ABOVE HAS PERFORMED BELOW PRE-SET
LEVELS OF PERFORMANCE ON TERMINAL OBJECTIVES IN LESSON 2

      T.O.            PERCENT ERROR       CUTOFF LEVEL

       21                   8                  0
       32                  11                  0
       33                  14                  0
       41                  10                  0
       43                  25                  0
       51                  12                  0
```

REPORT #7-2 Fig. 5 STUDENT TO PERFORMANCE



```
***A.I.M.S. REPORT GENERATOR***    REPORT NUMBER 7***
   TIME-07.23.16   DATE - 12/04/70    PAGE NUMBER 68

TERMINAL OBJECTIVE REMEDIAL SUMMARY
LESSON 2  TERMINAL OBJECTIVE 51   COMPOSED OF 8 QUESTIONS.
A TOTAL OF 9 STUDENTS PERFORMED BELOW THE CUTOFF LEVEL
SET AT 0.
THE FOLLOWING STUDENTS HAVE PERFORMED BELOW THE CUTOFF
LEVEL-

     NAME OF STUDENT        I.D. NO.         PERCENT ERROR
     STUDENT, KAREN           005                 12
     STUDENT, PHILIP          009                 12
     STUDENT, LOUIS           011                 37
     STUDENT, PAMELA          017                 25
     STUDENT, JOHN            021                 12
     STUDENT, LINDA           023                 12
     STUDENT, RICHARD         040                 25
     STUDENT, SANDRA          043                 12
```

REPORT #7-3 Fig. 6 CLASS TO PERFORMANCE

## J. OPTIMIZATION

Statistical analysis of group performance indicates areas where the instructional or testing materials are to be adjusted. This is an ongoing, self-healing process.

1. An Item Analysis is shown in Fig. 7. This lists the frequency of response to choices in a set of multiple choice questions. A sharp deviation in the error pattern indicates the need for investigation. For example, question 6 in the chart shows 5 incorrect selections for only 18 students.

```
      *** A.I.M.S. REPORT GENERATOR ***  REPORT NO. 6
       TIME - 06.22.00  DATE - 12/04/70   PAGE NO. 1

AIMS ITEM ANALYSIS
VOLUME 1  TYPE, PRETEST   SEGMENT 1
NUMBER OF SELECTIONS PER QUESTION, 5
-------------------------------------------------------

NUMBER OF TIMES EACH ANSWER CHOSEN

QUESTION                                           TOTAL
 NUMBER      A      B      C      D      E        ANSWERS
    1        0      0     17*     0      1          18
    2        0      0      0     17*     1          18
    3        0      1      0      0     17*         18
    4        1      0     16*     1      0          18
    5        1     15*     0      2      0          18
    6        0      5      0     12*     1          18
    7        0     14*     1      1      2          18
    8        0      0      3      0     15*         18
    9        1     16*     0      0      1          18
   10        4      1     13*     0      0          18
TOTAL        7     52     50     33     38         180
SELEC.

* correct response

NUMBER OF WORKS PROCESSED        18

NUMBER OF MULTIPLE SELECTIONS     0

NUMBER OF BLANK SELECTIONS        0
```

Fig. 7

2. A Histogram is shown in Fig. 8. This frequency chart can be applied to the statistics relating to any Study Guide segment as well as to any test.

   Note: "SCOR." indicates the possible test scores.

   "STUD." indicates the number frequency of students achieving the score above.

   The column to the left is the frequence scale.

   (Refer to the glossary on page 47 for a complete list of definitions.)

```
          ***A.I.M.S. REPORT GENERATOR*** REPORT NO. 4***
          TIME - 06.29.07  DATE - 12/04/70  PAGE NO. 1
          AIMS HISTOGRAM ANALYSIS FOR GCHS
VOLUME 1           TYPE, STUDY GUIDE       SEGMENT 5
22
21
20
19
18                                                       *
17                                                  *    *
16                                                  *    *
15                                                  *    *
14                                                  *    *
13                                                  *    *
12                                                  *    *
11                                                  *    *
10                                             *    *    *
 9                                             *    *    *
 8                                             *    *    *
 7                                             *    *    *
 6                                             *    *    *
 5                                             *    *    *
 4                                        *    *    *    *
 3                                        *    *    *    *
 2                                   *    *    *    *    *
 1                         *    *    *    *    *    *    *
 0-----------------------------------------------------------
SCOR.   ...55   60   65   70   75   80   85   90   95  100
STUD.       0    0    0    1    1    2    4   10   17   18
NUMBER OF ZERO VALUES IN SAMPLE = 0
```

Fig. 8

3. A Volume Summary is shown in Fig. 9. This is an excerpt from the complete volume summary. This printout can be called for at any time. It accumulates all information submitted under the self-paced mode. The cumulative average is a summary for all previous volumes. This summary together with the histogram (Fig. 8), gives an overall view of the general performance of the entire class on any one volume.

   Note: The symbols and abbreviations found in this printout report are defined in the glossary (pages 47 ff.)

## III. EVALUATION

The outcome of the combined efforts of the computer and course developing teams has resulted in an innovative method of instruction with far reaching pedagogical implications.

a. Self-pacing is achieved through both the compartmentalized course structure and the computer program's capability to monitor individual performance. These permit a student either to remain in a certain segment because of difficulties he may be having, or to accelerate beyond the pace of the other students without interfering with course operation.

b. Immediate intrinsic remediation is presented to the individual student whenever he has responded incorrectly to a Study Guide question.

c. The role of the teacher has been redefined. The instructor of the course is relieved of the general duties normally associated with teaching a class.

   1. He does not have to prepare a lesson, the reading assignment, or the homework assignment;

```
***A.I.M.S. REPORT GENERATOR***  REPORT NUMBER 15*** TIME - 01.33.45  DATE - 12/05/70 PAGE NO. 1

                                      ***VOLUME SUMMARY***

COURSE, GCHS  VOLUME NO. 2

NOTE, THE ** SIGNIFIED THAT NO MATERIALS HAVE BEEN SUBMITTED FOR PROCESSING

                   #
                   PRE.     STUDY    STUDY    STUDY    STUDY    STUDY    HOME    POST    PERF.   CUM.
STUDENT       CSN  TEST     GDE(1)   GDE(2)   GDE(3)   GDE(4)   GDE(5)   WORK    TEST    INDEX   AVE.

STUDENT, A    1     0.**     98.      98.      98.      98.      93.     0.**     90.     97.     90.
STUDENT, B    2     0.**     95.      95.      98.      87.      95.     0.**     80.     94.     50.
STUDENT, C    3    60.       95.      89.      93.      89.      94.     0.**     70.     92.     75.
STUDENT, D    4    70.       96.      97.      98.      91.      91.     0.**     60.     94.     50.
STUDENT, E    5    70.       90.      65.      72.      70.      92.     0.**     40.     77.     45.
STUDENT, F    6     0.**      0.**    92.      95.      99.      95.     0.**     80.     95.     80.
STUDENT, G    7    90.       98.      97.      93.      90.      81.     0.**     70.     91.     70.
STUDENT, H    8     0.**     97.      98.      94.      92.      99.     0.**     80.     96.     85.
STUDENT, I    9    90.       96.      97.      92.      94.      88.     0.**     70.     93.     75.


# PRETEST USED AS FOLLOW-UP TEST AFTER PERFORMANCE ON POSTTEST
```

Fig. 9

2. He does not have to prepare and mark the weekly tests;

3. He does not have to maintain a daily grade record book.

All of this has been done by the writing teams and is incorporated as a fundamental part of the course materials. The instructor is, therefore, free to concentrate on individualized instruction.

d. The computer program furnishes a list of the objectives in which each student is found deficient (Fig. 5). This becomes the basis for a short, effective, one-to-one tutoring session.

e. The computer program furnishes a list of students who have indicated weaknesses in certain objectives (Fig. 6). This becomes the basis for a group remedial session conducted by the teacher.

f. Records of individual performance and specific remedial prescriptions are furnished to each student routinely (Fig. 4).

g. Summaries of class performance on each of the varied components of the course are constantly made available as item analyses (Fig. 7), histograms (Fig. 8), and volume summaries (Fig. 9), thus obviating the need for extensive record keeping.

h. One end result is a more efficient use of the teacher's time and ability, and a more meaningful course of study for the individual student.

i. A second result is the paradoxical situation where the student-teacher ratio may be increased at the same time that the individual attention and remediation afforded a single student is also increased.

## IV. SUPPORT MATERIAL

### A. SOFTWARE

1. The complete full year program based upon the design described in the previous section requires an extensive array of supporting software.

2. Two different lists are prepared which distinguish the materials according to the person using them.

   a. Needed by the instructor (Fig. 10)

   b. Needed by the student (Fig. 11)

3. Each of these lists is divided into three sections to indicate the role that the software plays in the course.

   a. Instruction program

   b. Testing program

   c. Course operation

4. To specify the manner in which the material is to be handled, each item of software is classified according to the following code:

   a. O Re-usable

   b. X Expendable (must be replaced)

   c. * Security required

5. A complete set of the listed software material is on file at the Learning Management Resources Center of the New York Institute of Technology, Old Westbury, New York.

| References: | | |
|---|---|---|
| | 1-18 | PMC STUDY GUIDE VOLUMES |
| | 19 | PMC HANDBOOK |
| | 20 | MBO BOOK |
| | 21 | MASTER FILE OF SOFTWARE |

NYIT
PMC

SOFTWARE REQUIREMENTS

NEEDED BY INSTRUCTOR:

USE CODE:
0 re-usable
X expendable
* security required

| ITEM NO. | USE CODE | DES. OF SOFTWARE: | NO. REQUIRED |
|---|---|---|---|
| 1. | 0 | HANDBOOK | 1 |
| 2. | 0 | SIM SUPPLEMENT | 1 |
| 3. | 0 | MBO BOOK | 1 |
| 4. | 0 | STUDY GUIDES | 1 set of 18 |
| 5. | *0 | VISIBLE PAGINATION | 1 set of 90 |
| 6. | *0 | COMPUTER ANS. MATRIX | 1 set of 90 |
| TESTING PROGRAM: | | | |
| 7. | *0 | PRE-TEST | 1 set of 18 |
| 8. | *0 | ANS. KEY | 1 set of 18 |
| 9. | *0 | POSTTEST | 1 set of 18 |
| 10. | *0 | ANS. KEY | 1 set of 18 |
| 11. | *0 | MIDTERM (FORM A) | 1 |
| 12. | *0 | ANS. KEY | 1 |
| 13. | 0 | CROSS REFERENCE | 1 |
| 14. | *0 | MIDTERM (FORM B) | 1 |
| 15. | *0 | ANS. KEY | 1 |
| 16. | 0 | CROSS REFERENCE | 1 |
| 17. | 0 | MIDTERM PRESC. BOOKLET | 1 |
| 18. | *0 | FINAL (FORM A) | 1 |
| 19. | *0 | ANS. KEY | 1 |
| 20. | *0 | FINAL (FORM B) | 1 |
| 21. | *0 | ANS. KEY | 1 |
| COURSE OPERATION: | | | |
| 22. | X | CONTROL SHEET | 2 per student |
| 23. | 0 | MBO CROSS REF. LIST | 1 set of 18 |
| | X | (if using SIM mode) | (1 set per student) |
| 24. | X | HOMEWORK MARKING SHEET | 1 set of 18 per student |
| 25. | 0 | LATENT IMAGE ERRATA | 1 |
| 26. | 0 | STUDY GUIDE ERRATA | 1 |

Note: See glossary (pages 47 ff.) for a description of the abbreviations found above.

Fig. 10

NYIT
PMC

SOFTWARE REQUIREMENTS

NEEDED BY STUDENT: USE CODE:
0 re-usable
X expendable
* security required

| ITEM NO. | USE CODE | DESC. OF SOFTWARE: | NO. REQUIRED |
|---|---|---|---|
| INSTRUCTIONAL PROGRAM: | | | |
| 1. | 0 | MBO BOOK | 1 |
| 2. | 0 | STUDY GUIDES | 1 set of 18 |
| 3. | X | STUDY GUIDE RESPONSE FORM #6006 | 1 set of 90 |
| 4. | X | CONTROL SHEET PLAN A or PLAN B | 2 |
| TESTING PROGRAM: | | | |
| 5. | *0 | PRETEST (FORM B) | 1 set of 18 |
| 6. | *0 | POSTTEST (FORM A) | 1 set of 18 |
| 7. | 0 | POSTTEST PRES. (if SIM) | 1 set of 18 |
| 8. | *0 | MIDTERM (FORM A) | 1 |
| 9. | *0 | MIDTERM (FORM B) | 1 |
| 10. | 0 | MIDTERM PRES. | 1 booklet |
| 11. | *0 | FINAL (FORM A) | 1 |
| 12. | *0 | FINAL (FORM B) | 1 |
| 13. | X | TESTING RESPONSE FORMS | |
| | | (if AIMS #6007) | 40 |
| | | (if SIM #1451) | 40 |

Note: See glossary (pages 47 ff.) for a description of the abbreviations found above.

Fig. 11

## B. THE HANDBOOK

A Handbook has been created for the information of the course supervisor and instructors.

1. Rationale: The first chapter contains a brief description of the origins of the project, its objectives and anticipated outcomes.

a. A description of the scope of the course, a listing of the required texts and a suggested time schedule is followed by a complete outline of the syllabus.

b. Each lesson, as itemized in the syllabus, is accompanied by references to the three texts associated with the course. These references outline the general reading and study assignments for each lesson.

2. Strategies: The second chapter of the handbook provides an itemized summary of the strategies and logistics involved in the installation and operation of the course.

   a. Each component of the course is described in detail with reference to the objective features, the purpose, the method of use and the relationship of the component to the entire program.

   b. The physical facilities and personnel requirements for the optimal operation of the course are specified.

   c. This chapter concludes with a reconstruction of the successive steps that a student must follow as he progresses through the course.

   d. Two different plans, one designed for the student who has had previous exposure to the course materials and a second designed for the student who is taking the subject for the first time, are presented in flow-chart form.

3. Replication: The third and final chapter of the Handbook outlines the principles and procedures to be followed in the creation of a course in any discipline based upon the PMC model.

   a. The first section outlines the chronological sequence to be followed in the structuring of the several course components.

   b. The subsequent sections discuss:

- the philosophy fundamental to differentiating between the levels of learning difficulty;
- the strategy of question placement in the several course components relative to the learning levels;
- the use of the multiple choice question mode;
- the principles for creating a set of criterion checks; and
- a discussion of the various distractor strategies.

c. The final section describes in detail the several forms that have been devised to implement the orderly and efficient production of the entire course. Specific exhibits of the forms associated with the following activities are presented:

  - Study Guide question creation
  - Study Guide manuscript answer matrix
  - Test question worksheet
  - Test answer matrix for computer input
  - Test evaluation check list
  - Homework assignment worksheet
  - MBO strategy and cross reference sheet

d. The Handbook concludes with a thorough discussion of the procedures to follow in executing the scrambled pagination procedures used in the printing of the Study Guides.

## V. UTILIZATION OF THE SYSTEMS ANALYSIS APPROACH

It is stated in the original proposal that all activities relevant to meeting the requirements of the contract would follow the procedure known as Systems Analysis. The technique requires an overall attack on the problem with specifications outlining the sequential steps in the development of the solution to the problem.

After definition of the ultimate goal as abstracted in the title of the original proposal, "The Individualization and Optimization of Learning Through Computer Management of the Educational Process," the following preliminary steps were taken in Phase I:

a. An assessment of the existing conditions which would form the platform on which the program was to rest. This included:

    1. the identification of current course objectives;

    2. an inventory of instructional materials;

    3. an examination of existing criteria assessment measures;

    4. a review of the existing programs of instruction that are susceptible to computer monitoring; and,

    5. a survey of the state of the computer art.

b. An examination of the target student population. This involved:

    1. an analysis of student abilities and performance obtained from a survey of school records including standardized tests in the existing methods of instruction;

    2. a survey of the future occupational goals and educational needs of the proposed student body; and

    3. an analysis of student reaction to existing courses using computer-monitored programmed instruction.

c. A development of syllabi for the proposed courses of study.

    1. An intrinsic part of this activity was the determination of the terminal objectives appropriate to the findings in the study of existing conditions

and student populations.

2. The development of the syllabus for the PMC Level I is discussed in Section VI of this presentation.

d. The creation of a course structure that would lead to the realization of the objectives, and would be suitable for computer monitoring.

Application of the steps of the Systems Analysis approach in the joint and parallel construction of the computer management system and the creation of the Programmed Mathematics Continuum began in Phase I and continued in Phase II.

e. The measurable behavioral objectives were developed following the general course syllabus outline as expressed in the list of terminal objectives.

    1. They were coded for ease of handling by the computer monitoring system and for ease of correlation with the instructional items and criterion checks in the course materials.

    2. The development of the MBO List is reviewed in Section VII.

f. The course structure and instructional strategy were designed to enable the student to progress through a course in an individualized and self-paced manner. At the same time, elements that would conflict with the basic principles of data-analysis input were carefully avoided.

g. The design for the Programmed Mathematics Continuum included the following combination of the available instructional media:

    1. Off-line computer managed instruction;

    2. Reference to standard texts;

    3. Reference to remedial texts;

    4. Instruction using the written work and diagrams;

    5. Multiple choice questions;

6. Written remedial instruction for incorrect responses;

7. Homework assignments requiring constructed answers;

8. A pair of parallel tests for each Study Guide volume, one test accompanied by remedial prescriptions applying to specific errors;

9. Two forms of a midterm examination (one with remedial prescriptions);

10. Two forms of a final examination;

11. Provision for individual tutoring;

12. Provision for group remedial instruction.

h. The computer program was structured and implemented to receive the input data, process it, store the information and generate printouts and analyses of individual and group performance that would be of value to the course developers, the teachers, and the students taking the course.

i. Constant contact between the course developers and the computer program developers was maintained in an effort to establish a workable articulation between the two efforts.

j. Continuous feedback between the two groups--the course developers and the computer program developers--was effected to arrive at a viable computer system and an integrated course.

## VI. THE DEVELOPMENT OF THE PMC SYLLABUS

a. A preliminary statement of a plan of action to implement the proposal for the development of a programmed course capable of being monitored by the computer was outlined in an internal memorandum (July 1968) from the project director to the principle investigators. Excerpts appear below:

1. Immediate Objective: "In time for the opening of the Fall 1968 semester, it is expected that a set of unit tests will be composed that will be in a direct correspondence with the sequence of units as presented in the current Math 3012 course . . . offered under the supervision of the Office of Special Education of the New York Institute of Technology where the subject matter is essentially the material considered prerequisite for admission to the traditional Calculus . . . ."

2. Test Administration: " . . . the testing operation will be removed from the concern of the teacher and the clerical details involved in the administering, proctoring, and marking of the tests, along with the analysis of individual test results with the appropriate recommendations for further remedial work, will be the task of the test group . . . ."

3. Question Mode: "Each test question will have a multiple choice format for the answers. Each of the incorrect choices will be chosen to illustrate a typical mistake; one that a student would arrive at if he misapplied a principle. The incorrect choice would be key-coded with a master list of all the concepts in the course outline . . . ."

4. Stored Prescriptions: "Stored in the computer will be coded reference material which is applicable to each of the errors contained in the list of multiple choice answers . . . ."

5. Anticipated Feedback: "As the set of tests is used, the feedback will allow for validation and upgrading of the test questions themselves. It is also expected that the improved tests will produce valuable data relevant to the content and the teaching methods employed . . . ."

6. Ultimate Objective: "It is expected that an off-line programmed Study Guide will be

developed incorporating as the test material the improved test questions developed by the computer testing procedure outlined above . . . ."

b. Revised Plan of Action - The sequence for implementation of the preliminary plan is outlined in the excerpts contained in a second memorandum to the investigators.

   1. Plan Update: "It is to be understood that as investigation proceeded and new information was received adjustments were made in the original concept of the project plans . . . ."

   2. Syllabus Examination: " . . . if the immediate objective was the creation of a computer managed test for the course Math 3012 then the syllabus must be examined. Investigation showed that there were three variants of the course syllabus; each was a mere tabulation of the table of contents of a textbook; each has been dismissed by the three teachers of the course as being inadequate . . . ."

   3. Population Analysis: "The next area of investigation concerned the determination of the student population that would be taking the course Math 3012, for any unusual deviation from a normal distribution of background and skills would affect the stress and emphasis placed on the various topics, the level of instruction and the intensity of the testing program. . . . This was accomplished after a discussion with the admissions office, the office staff of the Office of Special Education and interviews with the teaching staff . . . ."

   4. Textbook Adoption: "A critical survey of the textbooks that had been used and others resulted in the adoption of Intermediate Algebra for College Students by Petersen, published by Harper and Row, 1967 . . . a second book . . . was also chosen for its rich source of well graded problems. It

is published by Amsco, and it is titled Ninth Year Mathematics . . . ."

5. New Syllabus: "A detailed syllabus was then created. (See Fig. 12.) It is subdivided into thirty-six sessions which are then grouped into ten units.

    a) References are made to the measurable behavioral objectives under the headings 'AH' which are algebraic theorems and principles and under 'AS' which are the companion skills required for their execution.

    b) Reference was also made to chapter and section in both of the texts for easy reference by teacher, pupil and testing personnel . . . ."

c. Certain inadequacies of the preliminary plan appeared during and after implementation. This resulted in the decision to revise the syllabus.

1. Adjusted Time Span: The Math 3012 course was a single semester course, whereas the Programmed Mathematics Continuum Level I was designed to be a full year course. Consequently, the number of topics handled and the time allowance would have to be adjusted.

2. Computer Feedback: The feedback from the computer program indicated, in the item analyses generated by student performance on the various tests that certain areas of difficulty would require more extensive treatment in the instructional program.

3. Text Substitutes: The students and instructors of the Math 3012 indicated dissatisfaction with the assigned text.

    a) A continuing survey of the textbook field resulted in the adoption of an outstanding text Modern Algebra, by Dolciani, et al, published by Houghton Mifflin, 1965.

## NEW YORK INSTITUTE OF TECHNOLOGY

### Office of Special Education

### MATH 3012 - SYLLABUS BY DAILY SESSION

| | | | | | References | | |
|---|---|---|---|---|---|---|---|
| | | | MBO | MBO | Book 599 | Book 597 | |
| Unit | Sess. | Topic | AH | AS | Section | Chapt. | Sect. |
| | | INTRODUCTION-EQUATIONS | | | | | |
| I | 1 | Organization; Book order; Introduction; Motivation; Outline of course | | 1-2 | 19,20 | | |
| | 2 | Symbols; Real number system; Laws of Algebra; Evaluation | 1-16 | 3 | 1-6 | I<br>III | 1-8<br>3-9 |
| | 3 | Laws of Algebra; Axioms | 17-20 | 4-9 | 11 | IV | 1-7 |
| | 4 | Simple Equations | 17-20 | 10-14 | 17,18 | V | 1-4 |
| | 5 | Simple Equations (cont.) | | | | V | 5-8 |

Excerpt from original syllabus for testing program math 3012

Time Period on Units - 5 Sessions Total

Book 599: Intermediate Algebra for College Students
By Petersen; Harper & Row 1967

Book 597: Ninth Year Mathematics
By Dressler; Amsco 1966

MBO Codes Refer to combined behavioral objective list.

Fig. 12

b) The review text was considered satisfactory and was retained.

c) A third text, Algebra I, by Dodes and Greitzer, published by Hayden, 1967 was adopted as an enrichment text.

4. Revised Syllabus: The writing team created an expanded and revised syllabus appropriate for a year course and cross referenced it with the three texts. It is included as a section in Chapter I in the Handbook.

## VII. EVOLUTION OF THE MBO LIST

### A. ORIGINAL TERMINAL OBJECTIVES

The original proposal included, as an appendix, a general list of objectives for an Elementary Algebra course.

1. This listed, in behavioral terms, what could be considered terminal objectives for the usual course as presented in most standard texts on the subject.
2. The objectives were numbered using paragraph notation. (See Fig. 13.)

### B. A STRUCTURED LIST OF OBJECTIVES

A second resource, previously prepared by the Math project leader, was adopted.

1. This was a detailed analysis of the syllabus for Ninth Year Mathematics (Elementary Algebra) as promulgated by the Bureau of Secondary Curriculum Development of the New York State Education Department.
2. This analysis divided the course content of Elementary Algebra into the four disciplines of arithmetic, algebra, geometry and trigonometry. Each of these was subdivided into the following categories: definitions, theorems and skills.

2. Students should be able to translate verbal phrases and sentences into algebraic symbols; that is, they must be able to use letters to represent numbers.

3. They should be able to find the value of a numerical expression using the following rules of operation:

    a. do all multiplications and divisions, taking them in order from left to right.

    b. do all the additions and subtractions after step one above, taking them in any order.

4. They should be able to evaluate algebraic expressions, including those containing parentheses.

5. They should be able to combine like terms.

6. They should be able to write word statements as equations.

7. They should be able to combine unlike terms.

8. Students should be able to solve and check simple equations with whole number coefficients using the following principles:

    a. Each member of an equation may be divided by the same number without destroying the equality.

    b. Each member of an equation may be multiplied by the same number without destroying the equality.

    c. The same number may be added to each member of an equation without destroying the equality.

    d. The same number may be subtracted from both members of an equation without destroying the equality.

Original Objectives

Fig. 13

3. This resource employed an alpha-numeric code that used a distinctive letter indicating the sub-discipline and a second letter designating the cognitive subset. See Fig. 14.

| | ARITHMETIC | ALGEBRA | TRIGONOMETRY | GEOMETRY |
|---|---|---|---|---|
| DEFINITIONS | RD | AD | TD | GD |
| THEOREMS | RH | AH | TH | GH |
| SKILLS | RS | AS | TS | GS |

Structured List Objectives

Fig. 14

The particular code letters were selected for their alliterative or mnemonic properties. ITEMS DRAWN FROM PREVIOUS STUDY - THE APPERCEPTIVE BASE - will be designated by prefixing an ASTERISK, e.g., "PRIOR ARITHMETIC SKILL"........*RS.

4. Under these individual headings the specific concepts were numbered sequentially and specified by a word or phrase. This code was the first of several that were devised for the quantification and identification of behavioral objectives.

5. The interrelation of objectives was indicated by identifying some as prerequisites for others that followed. This anticipated the terminal objective-enabling objective structure adopted later.

6. An excerpt of this resource is included in Fig. 15.

## C. COMBINED LISTING

These two resources--the original list of objectives and algebraic classification list--were cross-correlated into a joint list of behavioral objectives.

| | | | | |
|---|---|---|---|---|
| | SUBSTITUTION: | | | |
| AS1 | LETTERS FOR WORDS | *A1 | AH6 | *RX1 |
| AS2 | ALGEBRAIC FORMULAS FOR LAWS | *A1 | A2 | |
| AS3 | EVALUATION OF ALGEBRAIC EXPRESS. | | AH6 | *RX1 |
| | BASIC LAWS OF COMBINATION: | | | |
| AS4 | ORDER OF OPERATIONS | *RS31 | | *RH7 *RS1-19 |
| AS5 | COMMUTATIVE LAW FOR ADDITION | | AH7 | *RH1 *RS1,9,15 |
| AS6 | COMMUTATIVE LAW FOR MULT. | | AH8 | *RH2 *RS3,13,17 |
| AS7 | ASSOCIATIVE LAW FOR ADDITION | | AH9 | *RH3 *RS1,9,15 |
| AS8 | ASSOCIATIVE LAW FOR MULT. | | AH10 | *RH4 *RS3,13,17 |
| AS9 | DISTRIBUTIVE LAW | | AH11<br>AH12 | *RH5 *RS3,13,17 |
| | SOLUTION OF EQUATIONS: | | | |
| AS10 | BY ADDITION AXIOM | | AH17 | (AS15) AS7,5 |
| AS11 | BY SUBTRACTION AXIOM | | AH18 | (AS16) AS7,5 |
| AS12 | BY MULTIPLICATION AXIOM | | AH20 | (AS17) *RS3,13,17 |
| AS13 | BY DIVISION AXIOM | | AH19 | (AS18) *RS4,14,18 |
| AS14 | BY COMBINATION OF AXIOMS | | (AS10-AS13) | |
| | OPERATIONS WITH SIGNED NUMBERS: | | | |
| AS15 | ADDITION OF SIGNED NUMBERS | (AS21-AH24) | | *RS1,2,9,10,15,16 |
| AS16 | SUBTRACTION OF SIGNED NUMBERS | AH25 | | *RS2,1,9,10,15,16 |
| AS17 | MULT. OF SIGNED NUMBERS | (AS26-AH28) | | *RS3,13,17 |
| AS18 | DIVISION OF SIGNED NUMBERS | AH29 | | *RS4,14,18 |

NOTE: Reference codes on the right refer to prerequisite concepts or skills from algebra and arithmetic.

See page 29 for a definition of the coded symbols.

Original Structure - Algebraic Concepts

Fig. 15

1. This compilation became the first draft of objectives.

2. It was used as a foundation for the preliminary development of the testing program associated with Math 3012 course, and was also employed in the initial attempt at structuring a computer program capable of monitoring student performance.

3. An excerpt of this appears in Fig. 16.

| | | | | |
|---|---|---|---|---|
| 1.2 | | Students should be able to translate verbal phrases to algebraic symbols; that is, they must be able to use letters to represent numbers. | AS1, | AS2 |
| 1.3 | | They should be able to find the value of a numerical expression using the following rules of operation: | AS3 | |
| | 1.31 | Do all multiplication and divisions, taking them in order from left to right. | AS12-13,<br>AS23-28,<br>AS49-50 | AS17-18,<br>AS39-40, |
| | 1.32 | Do all the additions and subtractions after step one above, taking them in any order. | AS9-11,<br>AS19-22,<br>AS42-43, | AS15-16,<br>AS31-32,<br>AS4 |
| 1.4 | | They should be able to evaluate algebraic expressions, including those containing parentheses. | AS4-9,<br>AS14 | AS3, |
| 1.5 | | They should be able to combine like terms. | AS19,<br>AH21-25 | AD7, |
| 1.6 | | They should be able to write word statements as equations. | AS1-2 | |

Note: See page 29 for a definition of the coded symbols.

Objectives - Combined Listing

Fig. 16

## D. REVISED AND ENLARGED MBO LIST

As the project advanced from the preliminary stages of creating a testing program (to be used as an input source for the developing and testing of the primitive computer program) to the final production of a complete teaching and testing program (monitored by a sophisticated computer system) the feedback indicated the need for major revisions.

1. The objectives would have to be rewritten and cast in language appropriate to measurable behavioral objectives.

2. The alphanumeric coding system would have to be replaced by an enlarged numeric system that would be compatible with the language used by the program developers.

3. This requirement led to the revision of the coding system, making it possible to indicate the physical location of the behavioral objectives in the set of 18 Study Guides.

    a. This was accomplished by having the first two digits specify the volume number,

    b. the middle digit indicate the segment of the volume,

    c. the following digit indicate the number of the terminal objective, and

    d. the final digit specify the enabling objective relating to the TO.

## E. CONCEPT CATALOG

Feedback from the original testing program suggested that while a particular question tested the student's mastery of a given MBO, frequently an error was made due to a misapplication or misunderstanding of a prior objective.

1. It was decided to utilize the original structured list of objectives (Fig. 15, page 30) to relate the concept or skill with the specific error.

2. This list was recoded using a four digit numeric code which reflected the same classification that appeared in the listing.

3. The updated list of definitions, theorems and skills is titled the "Concept Catalog." This coded list is employed throughout the PMC for error identification.

The CONCEPT CATALOG and the MEASURABLE BEHAVIORAL OBJECTIVES are bound in one volume. It is designed for the use of students and teachers, and provides a complete listing of the objectives of the entire PMC Level I.

## VIII. HISTORY AND OPERATIONAL EXPERIENCE

### A. DEVELOPMENT OF THE PRELIMINARY COMPUTER PROGRAM TITLE: VICAR (Variable Input Computer Assembled Records)

1. Purpose

   A preliminary computer program was developed by the Advanced Systems Lab at the New York Institute of Technology as immediate support for the experimental testing program associated with the operation of the Math 3012 course. This course was the primary research tool in the development of the Programmed Mathematics Continuum.

   a. Operational techniques developed in the construction of this first program were to be incorporated into the design of the ultimate AIMS computer program.

   b. Feedback generated by this preliminary program was to influence the construction of the complete PMC with respect to question techniques and the assignment of time allotments for concept development.

2. Operational Features

   VICAR accepts the punch card response form used by the students in the testing program as the computer interface and generates the following printouts:

   a. For course organization:

      1) Student roster;

      2) Prescription master file;

      3) Determination of final grade;

      4) Re-ordering of students according to class rank;

      5) Assignment to homogeneous sections.

b. For the testing programs:

    1) Individual test scoring with prescriptions;

    2) Weighted scores for individual homework assignment;

    3) Cummulative scores for individual homework assignment;

    4) Individual student profile of scores;

    5) Weekly summary of student scores.

c. For course analysis:

    1) Histogram of total test performance;

    2) Item Analysis of individual test items;

    3) Flagging of extremely high or low scores.

3. Description of Printouts
Each of the printouts is fully discussed in the booklet entitled "VICAR" under these categories:

    a. Description of the contents;

    b. Facsimile of the printout;

    c. Rationale of the need for the printout;

    d. The Input required to generate the printout data.

## B. INSTALLATION AND REPLICATION EXPERIENCE

1. Articulated Multimedia Physics

    a. The AMP course has been operating as the regular course offering PHYSICS 4001 in the department of Special Education, on both campuses of the New York Institute of Technology, since the inception of Phase I. It is now offered as one of the courses in the Department of Physics.

        1) The validation of the course materials has been completed.

2) The operation of the course in the automated lab of N.Y.I.T. has served as a continuous demonstration of the utilization of multimedia presentation of instructional material.

3) The VICAR program demonstrated its adaptability by serving as the preliminary monitoring system for AMP during the development of the AIMS system.

4) The completely operational AMP became the first test ground for the debugging of the preliminary versions of the AIMS program as it was being developed.

b. The AMP course was installed at Shaw University, Raleigh, North Carolina during Phase II,

   1) to serve as a regular course offering utilizing innovative multimedia features, and

   2) to set up an experiment in long distance transmission of data between the user and the computer.

c. Two systems were considered for effecting the required data transmission. The following remarks are excerpted from a report by the Advanced Systems Lab. "An initial analysis . . . presents the following possible solutions:

   1) A 065-068 card-read punch telephone communication link with a multi-read RPQ and a reproducer . . . . Note: transmission rate is three cards a minute . . . .

   2) Manual paper tape punching of student performance data from PortAPunch card followed by high-speed paper tape transmission via teletype link to paper tape reproducer at N.Y.I.T.; then direct paper tape input to computer . . . ."

d. The strategies tested in the data transmission are outlined graphically on pages 36 and 37 of the PMC Handbook.

e. The findings from this installation are discussed in section C, "CONCLUSIONS DERIVED FROM THE SEVERAL COURSE OPERATIONS," on page 39.

f. The AMP course has recently been installed at Springfield Technical Community College, Springfield, Massachusetts, under the SIM/AIMS MODE. See section D, "DEVELOPMENT OF THE SIM/AIMS MODE," on page 41.

2. The Programmed Mathematics Continuum

a. The PMC course has been operating as the regular course offering MATH 3012 in the Department of Special Education on both campuses of the New York Institute of Technology since the beginning of Phase II.

1) The validation of the course material has been completed.

2) The PMC is operated as a completely self-paced and individualized course.

a) Students are permitted to advance as rapidly as they can demonstrate mastery of the material.

b) Students having difficulty in a specific area are allowed to remain in that portion of the course, receiving individual tutoring until they are able to proceed.

c) The teacher in the course functions primarily as a tutor and resource guide.

d) Most administrative and clerical tasks are handled by the course clerk.

3) Detailed examination of course operation and its articulation with the computer program has led to extensive debugging of both programs.

4) A dump of the updated question file (which is a listing of all the answer keys for the entire course) is on file at N.Y.I.T.

5) A latent image response form is used in conjunction with the Study Guide.

6) Input to the computer takes place by scanning mark sense images.

7) The findings of this operation are discussed in section C, "CONCLUSIONS DERIVED FROM THE SEVERAL COURSE OPERATIONS." (Page 39.

b. The PMC is presently installed at Glen Cove High School, Glen Cove, New York, as one of the regular offerings in Ninth Year Mathematics.

1) Two of the several groups scheduled for Ninth Year Math were assigned, with the approval of the students and their parents, to classes employing the PMC as an experimental plan.

   a) One group, under the direction of the chairman of the department, is being conducted in a self-paced mode.

   b) The second group, under the direction of a regular teacher from the department, operates within a two-week readjustment span so that the students begin the same Study Guide volume at the same time.

   c) Both teachers have, as part of their full teaching schedule, other classes in Ninth Year Math conducted in the traditional manner.

2) Other members of the General Math Course have been allowed to try the course as individual students in a self-study form of instruction when they have shown the interest and capability to do so. For the most part, these have been students that have recently overcome a language problem.

3) The two teachers are experimenting with the facility of the Student-Instructor Managed (SIM) operation mode without the services

of a clerk to conduct the program, while the AIMS III program monitors the operation on a weekly summary basis. A complete exposition of the SIM Mode is given in Section D, page 41.

4) Latent image mark sense response forms are used exclusively in this operation.

5) A complete file of the AIMS printouts for the entire course operation to date is kept at the Learning Management Resource Center at the New York Institute of Technology, Old Westbury, New York.

c. The PMC was installed at Bowie State Teachers College, Bowie, Maryland, during Phase II.

1) The prime purpose of this installation was to furnish the student body with a much needed course in remedial mathematics.

2) Punch cards were used as control interfaces for both tests and Study Guides.

3) The packs of punch cards were physically transported to the computer center for processing by the AIMS III System.

4) The findings of this operation are discussed in section C, "CONCLUSIONS DERIVED FROM THE SEVERAL COURSE OPERATIONS," page 39.

d. The PMC is being installed at Springfield Technical Community College, Springfield, Massachusetts, in the Special Education Department.

1) The staff will explore the operation of the SIM Mode as a self-supporting system until their computer facility is able to accept the file and data handling requirements of the AIMS III Program.

2) The preliminary indoctrination of the staff has been completed.

3) It is anticipated that this operation under the SIM Mode, without immediate application of the AIMS III System, will prove to be an excellent indoctrination procedure to prepare

the staff for the eventual application of the sophisticated computer program.

## C. CONCLUSIONS DERIVED FROM THE SEVERAL COURSE OPERATIONS

### 1. Need for Training of Course Operators

a. It was found in each of the installations, including the on-campus installation at N.Y.I.T., that the instructors and clerks attempted to run the course with only a general understanding of the purposes and functions of the various course components.

   1) Believing that knowledge of the subject was sufficient, and that the course would "run itself," the instructors assumed the role of interested observers and helped the students only when asked.

   2) In many cases, the existence of certain cross checks, remedial prescriptions, analyses generated by the computer and the rich background material was ignored because of unfamiliarity with their functions.

b. The situation can be corrected by requiring a series of indoctrination seminars spread over a period of weeks to be held prior to the beginning of the course. They should be scheduled for the purpose of discussing the underlying educational philosophy and the consequent adjustment in methods that have to be made. This could be extended into an internship phase that would parallel the period of the actual course operation.

### 2. Need for Student Motivation

a. Although many students were inspired to study at an accelerated pace, capitalizing on the self-pacing facility of the course structure, others took this feature to be an open invitation to be absent or to make mere token attempts to learn the concepts.

b. This situation calls for an administrative ruling listing the hours of attendance and noting the need for students to make an effort to maintain a steady progress through the materials.

1) This also emphasizes the need for the teacher in the course to establish a friendly and helpful attitude toward the students while constantly motivating them to strive for success.

2) This can be accomplished in the individual tutoring sessions and also in the group meetings. It is advisable to schedule a periodic session for the discussion of general topics of interest related to the subject.

3. Need for Training in the Use of Response Devices

a. Most of the errors in the computer printouts are caused by faulty recording of data by the students.

1) Errors are made in the identifying codes placed on the response devices. These include omitted numbers, failure to right-justify the correct code, and the use of the incorrect type code for the work being submitted.

2) Multiple responses on tests which call for single answers also garble the data stored in the computer.

3) Careless use of the stylus in handling the punch card response device, or the use of some other inappropriate tool such as an oversized ball-point pen mutilates the card and prevents its acceptance by the card reader.

b. These human errors can be minimized by proper indoctrination at the beginning of the course.

1) Emphasis should be placed on the value to be gained from the statistical information that can be generated by the computer when it receives correct input.

2) The response materials should be examined immediately by the course instructor for correctness and completeness of identifying information.

c. The difficulty encountered in the processing of punch cards led to the development of the latent image mark sense sheet as an interface device.

    1) A preliminary reader device converts the acceptable information to a tape for computer input and rejects the faulty codes without jeopardizing the entire information file maintained within the computer.

    2) The cost effectiveness of using a printed form to replace the combination punch card and light panel program control is a desirable consequence of this procedural change.

4. The Need for the Development of a Parallel Management System

    a. Since it is improbable that all causes of error in the input data can be eliminated, a human monitored control routine should be created as a "fail-safe" system to back-up the computer monitored system. This will insure smooth operation and continuous information flow to the students and instructor.

## D. DEVELOPMENT OF THE SIM/AIMS MODE

1. Response to Feedback Analysis

    a. Indoctrination - A master plan of action called the SIM/AIMS MODE was outlined as an indoctrination device that would orient the course operators and the students taking the course to the role each would assume.

        1) This system is necessary for the routine operation of the course while using the AIMS III monitoring program.

        2) The interrelation between the course components is highlighted by a graphic flow chart display of their functions.

        3) The procedures to be followed by each of the participants are listed in sequential steps.

4) Routines are established to control the flow of course materials in a simple systematic sequence.

b. Significance of Designated Title: SIM/AIMS - The operation of the course is continuously Student-Instructor Managed with the continual support of the AIMS Program.

c. Back-up "Fail-Safe" System Feature - This plan features a parallel back-up system in the form of an option device which permits the continuous operation of the course if there is any difficulty encountered in the transmittal of the data to the computer, in the operation of the computer, or in the prompt return of the printouts.

1) This option protects the student by insuring the continuity of course operation.

2) This back-up option is most effective in the installations where the operation is not in the immediate proximity of the computer facility.

3) Periodic submission of data is handled on a volume summary basis by the computer program while the moment-to-moment operation is conducted in the SIM Mode.

2. Principle Features of SIM/AIMS Mode

a. The Role of the Teacher - The provision for the assignment of a para-professional clerk who assumes most of the routine tasks in the course operation results in a redefinition of the role of the teacher.

1) The teacher is now free to furnish individual remediation when the need is revealed by the monitoring system without interfering with the progress of the other students.

2) Information generated by the system also indicates areas requiring group instruction. Such instruction may be carried on without jeopardizing the individualization and self-pacing aspects of the program.

3) Statistical analyses generated by the computer program or summaries maintained by the course clerk on the MBO CROSS REFERENCE LIST eliminate the need for extensive review of performance to locate the areas requiring remediation for each student.

4) The principal function of the teacher becomes that of motivation and remedial instruction.

b. The Role of the Clerk - The clerk is the immediate manager of the course operation. In this function the clerk:

1) maintains a chronological record of each student's activities by means of the Control Sheet (see Fig. 17);

2) issues materials to the student;

3) assembles response forms for delivery to the computer;

4) distributes printouts to the individual students;

5) key-scores test responses under the SIM option presented;

6) enters the incidence of response error on the MBO CROSS REFERENCE LIST when using the SIM option.

3. Course Logistics Under the SIM/AIMS Mode

a. The general sequencing of consecutive operations is presented in an abstracted flow-chart of course strategy which indicates the interrelation among the instructional-testing-remedial phases of the student-instructor managed course.

b. Separate flow charts found on pages 52 ff. present the sub-routines in detail.

| SUB-ROUTINE NUMBER | ROUTINE TITLE |
|---|---|
| 1 | PRE-TEST |
| 2 | STUDY GUIDE |
| 3 | REMEDIATION REFERRAL |

NYIT CONTROL SHEET
PMC STUDENT PROGRESS
1352 SOFTWARE DISTRIBUTION

PLAN B

STUDENT: ______________________
I.D. NO: ______________________
SECTION: ______________________

| | | VOL | VOL | VOL | VOL | VOL | VOL | VOL | VOL | VOL |
|---|---|---|---|---|---|---|---|---|---|---|
| PRE-TEST (TEST B) | ISSUED | | | | | | | | | |
| | COMPLETED | | | | | | | | | |
| | EXEMPT(?) | | | | | | | | | |
| VOL/SEG 1 | READING DONE | | | | | | | | | |
| | FORM ISSUED | | | | | | | | | |
| | FORM COMPLETED | | | | | | | | | |
| VOL/SEG 2 | READING DONE | | | | | | | | | |
| | FORM ISSUED | | | | | | | | | |
| | FORM COMPLETED | | | | | | | | | |
| VOL/SEG 3 | READING DONE | | | | | | | | | |
| | FORM ISSUED | | | | | | | | | |
| | FORM COMPLETED | | | | | | | | | |
| VOL/SEG 4 | READING DONE | | | | | | | | | |
| | FORM ISSUED | | | | | | | | | |
| | FORM COMPLETED | | | | | | | | | |
| VOL/SEG 5 | READING DONE | | | | | | | | | |
| | FORM ISSUED | | | | | | | | | |
| | FORM COMPLETED | | | | | | | | | |
| HOMEWORK | SUBMITTED | | | | | | | | | |
| | GRADED | | | | | | | | | |
| POST TEST (TEST A) | ISSUED | | | | | | | | | |
| | COMPLETED | | | | | | | | | |
| PRESCRIPT | ISSUED | | | | | | | | | |
| | COMPLETED | | | | | | | | | |
| TUTORIAL SESSION | ASSIGNED | | | | | | | | | |
| | COMPLETED | | | | | | | | | |

Fig. 17

| | |
|---|---|
| 4 | SUPPLEMENTARY INSTRUCTION |
| 5 | HOMEWORK |
| 6 | POSTTEST |
| 7 | RETEST |
| 8 | GUIDANCE REFERRAL |

c. Repetitive looping within the various routines and the branching to the remediation routine are indicated by means of numbered connectors.

d. Each chart specifies:

  1) the entry into the routine;

  2) the student, clerk, instructor, computer and counsellor activity;

  3) the record keeping maintenance by the clerk;

  4) the decision point locations;

  5) the departure destination.

e. Each of the sub-rountines follows a similar logistical pattern:

  1) Initiation: The clerk issues the course material, records the date, time and identifying information on the individual student's control sheet.

  2) Action: The student performs the assigned task, recording his action on a response device.

  3) Process: The clerk records the submission of the material by the student on the individual control sheet. Under the OPTION FEATURE the clerk either:

    a) forwards the response forms to the computer for processing, or

    b) compares the response with a master key and with a set of decision constraints determined by the instructor.

  4) Analysis: Under the OPTION FEATURE, the clerk either:

a) distributes the printouts and the generated prescriptions to the student for action, or

b) records all error responses on the individual MBO CROSS REFERENCE SHEET by circling the specific question number, tells the student his score and distributes the prepared list of prescriptions.

5) Decision: The clerk complies with the decision constraints and either recycles the student or completes a referral form.

f. Remediation Referral - The clerk completes the referral form directing the student to interview the instructor whenever the following occurs:

1) Study Guide: Multiple-answer choices greater than tolerance.

2) Supplementary Instructional Material: Incomplete assignment submitted.

3) Homework: Incomplete assignment submitted.

4) Posttest: Error frequency greater than tolerance.

5) Retest: Error frequency greater than tolerance.

g. Interview - The instructor receives the computer generated printouts or the MBO CROSS REFERENCE FILE from the clerk, arranges for a personal interview with the student, and effects the required remediation.

1) If the student is given a referral because of an unacceptable performance on the POSTTEST then the HOMEWORK ASSIGNMENT is forwarded to the instructor for detailed analysis and marking.

2) If the student requires guidance because of personal problems beyond the instructor's authority, then the instructor refers him to a guidance counselor.

# GLOSSARY

NOTE: Special terminology contained in AIMS Reports 13 and 14 is listed in one section at the end of this glossary.

| | |
|---|---|
| AIMS | Automated Instructional Management System |
| AIMS III | The revised form of the management system used during Phase II of the project. |
| AMP | Articulated Multimedia Physics; also referred to as Physics 4001 (N.Y.I.T.). |
| ANSWER MATRIX | A listing in chart form of question number and an array of answer choices as applied to multiple choice question format. |
| CONCEPT CATALOG | A coded list of algebraic concepts and skills, used to identify the probable cause of error in responding to a question designed to test a specific MBO. |
| CONTROL SHEET | A form on which is recorded all distribution and collection of materials in the operation of a course under the SIM/AIMS MODE. |
| CSN | Course student number. A number assigned to each student on the course roster. Generally in the same sequence as the alphabetical order. |
| C/W | The heading of a column indicating whether the answer choice to a question was correct (C) or wrong (W). |
| CUM/AVE | Cumulative average. The average of the previous weekly scores to date. |
| CUTOFF LEVEL | The cutoff level, also referred to as threshold level, is the tolerated percentage of error incedence. |
| DOS | IBM's disc operating system. Series of computer control programs which permit the machine to operate effectively. |
| EO | Enabling objective. An MBO prerequisite to achieving a TO or a sub-set belonging to a TO. |

| | |
|---|---|
| GCHS | Glen Cove High School |
| LATENT IMAGE RESPONSE SHEET | A response form that records the student's answer choice at the same time that it reveals a page number printed in invisible ink. |
| LESSON | In the physics program (AMP) a lesson is equivalent to a volume. The computer printouts use lesson and volume interchangeably. |
| MATH 3012<br>M 3012<br>COURSE 30 | Course in elementary algebra using the PMC I at N.Y.I.T., Special Education Department. |
| MBO | Measurable behavioral objective. A statement of a specific concept or skill that is to be learned by a student and the conditions under which his ability to demonstrate his knowledge is to be tested. |
| MBO CROSS REFERENCE | A listing of all MBO numbers and the questions that relate to them. |
| MESSAGE | A statement in the computer printout either describing the nature of the objective or listing a remedial assignment (prescription). E.g., 597/27.1-5 means in book 597, the student is assigned problems 1-5 on page 27. |
| N.Y.I.T. | New York Institute of Technology, Old Westbury, New York 11568. |
| OS | IBM's operating system. Series of computer control programs which permit the machine to operate effectively. |
| PHYSICS 4001<br>P 4001<br>COURSE 40 | Course in Physics at N.Y.I.T., Special Education Department using the AMP Program. |
| PMC | Programmed Mathematics Continuum Level I - Elementary Algebra. |
| PRESCRIPTION | A remedial assignment appearing on a test printout when a student has failed a particular question (see MESSAGE). |
| PSSC | Physical Science Study Committee. |
| REPORT | "Report" and "printout" are used interchangeably. |

| | |
|---|---|
| SEGMENT<br>SEG. | A part of a volume. In the Math Program (PMC) a volume is divided into five segments. In the Physics Program each lesson has only one segment. |
| SIM/AIMS MODE | A Student-Instructor managed routine controlling the distribution and collection of materials. It contains the option of sending the response form to the computer for processing or of having them hand graded as a back-up, fail-safe feature. |
| STUD. GDE.<br>S.G. | Study Guide volume, one of a set of instructional materials using a branching program with multiple-choice questions and presented in scrambled pagination form. The latent image response sheet is employed in working through the S.G. |
| STUD. GDE. 1 | An abbreviation in printouts employing Segment 1 of the Study Guide, Segment 2 of the Study Guide, etc. |
| STUD. | A short form for student. |
| THRESHOLD LEVEL | See cutoff level. |
| TO | Terminal objective. A major MBO. |
| TYPE<br>TYP. | Type of input arising from student response to different parts of a lesson or volume. Type 1, Pretest; Type 2, Posttest; Type 3, Homework; Type 4, Study Guide Segment; Type 5, Worksheet Assignment. |
| VICAR | Varied Input Computer Assembled Records. The original computer program comprising 13 printouts later assimilated into AIMS III. |
| VISIBLE PAGINATION | A key for the use of the instructor of the information that appears in the latent image response sheet. |
| VOLUME<br>VOL. | An individually bound basic unit in the PMC course equivalent to a lesson in the AMP Course. |

Special terminology and abbreviations appear in the AIMS III Printout Reports 13 and 14 which apply to the AMP Physics Program. Many of the abbreviations were the unofficial inventions of the key-punch operators in an effort to effect a maximum use of the available areas assigned in the printouts.

Printout Report 14 refers to index scores for individual students. In each instance the raw scores are converted to a percent in the form of a number between zero and one hundred.

| | |
|---|---|
| CAPB. IND. | Capability Index. Derived from a weighted average of available background information of the student's math and verbal SAT scores, rank in high school graduating class, and achievement in mathematics and physics. |
| PERF. IND. | Performance Index. Derived from two separate evaluations, the Study Guide sub-index and the Worksheet sub-index which are given weights of 3 and 1 respectively. The two sub-indices are found by dividing the number of correct answers by the total number of available choices. |
| PROB. ACH. | Problem Achievement Index. Derived from totalling the marks assigned to a set of homework or worksheet problems and converting the total to a percent. |
| POSTTEST ACH. | Posttest Achievement Index. Similar to the Problem Achievement Index but relating to the Posttest. |
| NET ACH. | Net Achievement Index. The arithmetic mean of the two previous indices. |
| ABS. PERF. DEV. | Absolute Performance Deviation Index. The difference between the Performance Index and the Capability Index. |
| REL. PERF. DEV. | Relative Performance Deviation Index. The difference between the Absolute Performance Deviation and the Group Performance Deviation. |
| ABS. ACH. DEV. | Absolute Achievement Deviation Index. The difference between the Net Achievement Index and the Capability Index. |
| REL. ACH. DEV. | Relative Achievement Deviation Index. The difference between the Absolute Achievement Deviation and the Group Achievement Deviation. |

NOTE: The following summarize thevarious scores obtained in all previous lessons.

| | |
|---|---|
| CMAV. PROB. ACH. | Cumulative Mean Problem Achievement Index. A summation of the student's problem achievement for all the previous lessons converted to a percent. |
| CMAV. PT.T. ACH. | Cumulative Mean Posttest Achievement Index. A summation of the student's posttest achievement for all the previous lessons converted to a percent. |
| CMAV. NET. ACH. | Cumulative Mean Net Achievement Index. A summation of the student's net achievement for all the previous lessons converted to a percent. |
| CMAV. REL. ACH. DEV. | Cumulative Mean Relative Achievement Deviation Index. A summation of the student's relative achievement deviation for all the previous lessons converted to a percent. |

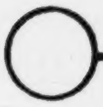
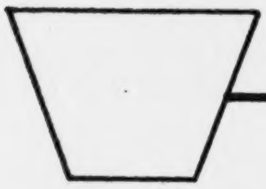
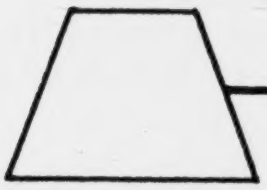
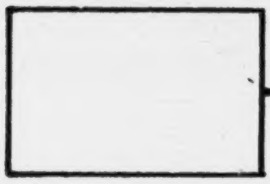
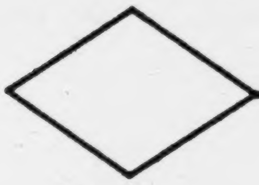
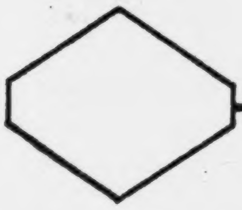
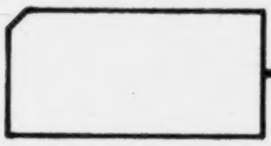
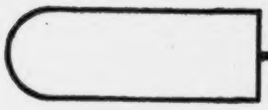
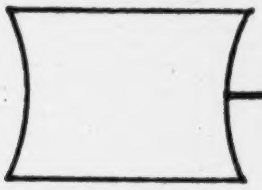
Printout Report 13 refers to index scores pertaining to the entire class.

For each of the listed Indices

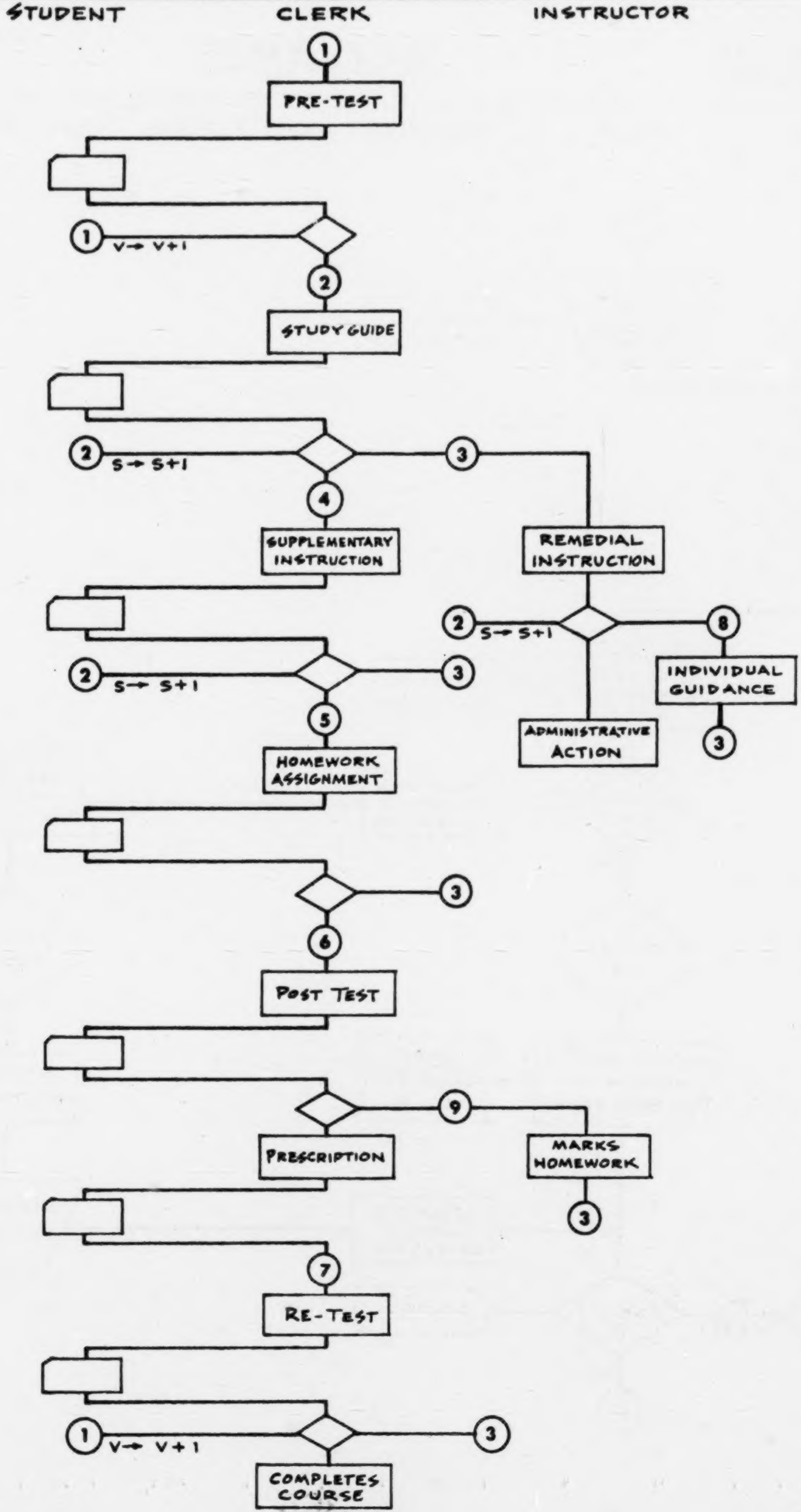
the MINIMUM SCORE
the MAXIMUM SCORE, and
the ARITHMETIC MEAN of all the scores are listed.

# LEGEND

THE FOLLOWING SYMBOLS ARE EMPLOYED IN THE FLOW CHARTS

| | | |
|---|---|---|
|  | CONNECTOR | at the beginning or end of a sub-routine |
|  | ACTION | to a person |
|  | ACCEPTS | from a person |
|  | PROCESS | done by the person |
|  | DECISION | based on established criteria |
|  | SCORES | compares with answer matrix |
|  | RESPONSE | any response form:<br>punch card<br>latent-image |
|  | CONTROL | a chronolog of the action |
|  | MBO CROSS REFERENCE FILE | master file of all error instances cross referenced |

## NEW YORK INSTITUTE OF TECHNOLOGY **PMC - SIM** ABSTRACTED FLOW CHART

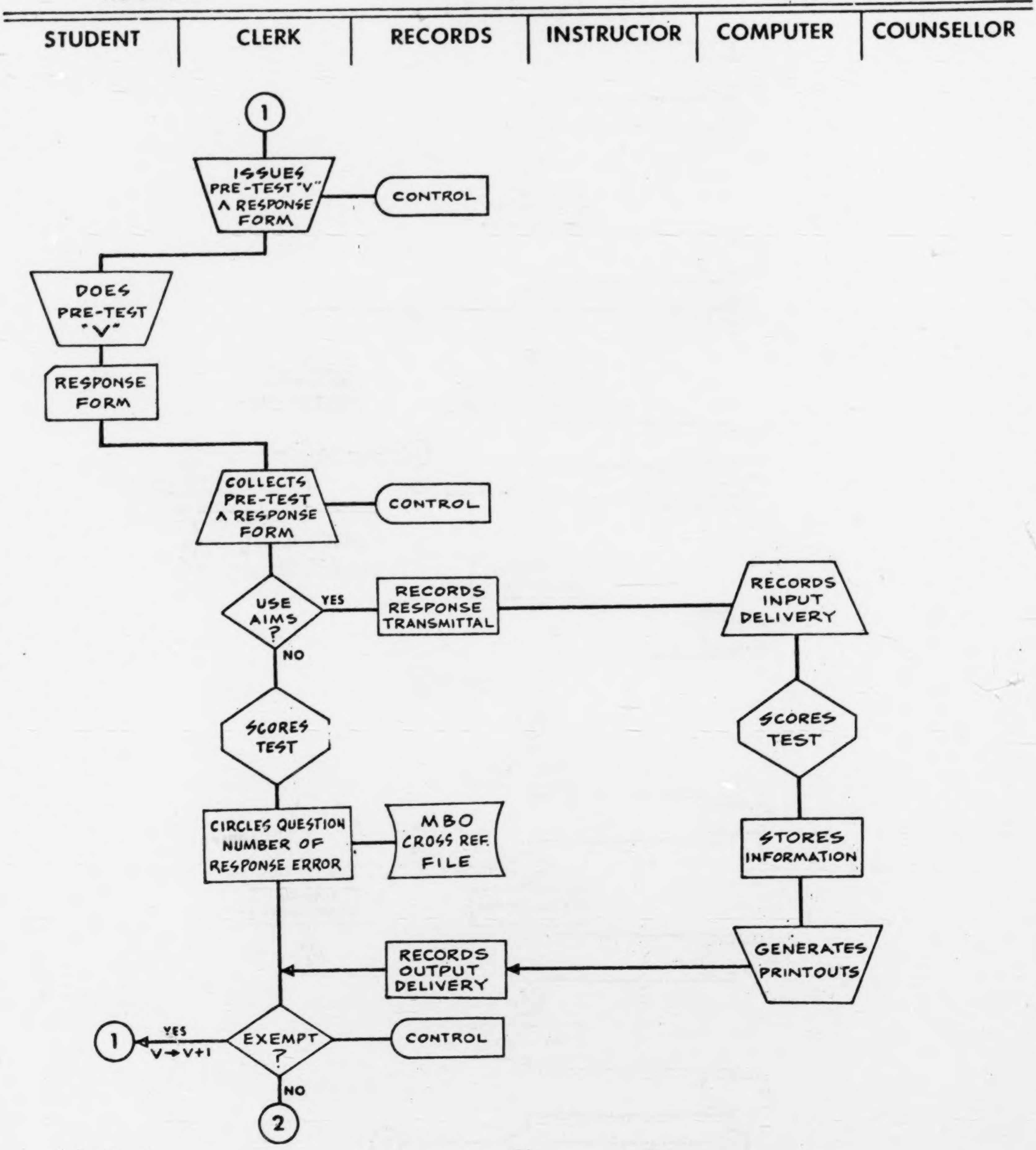

STUDENT
CLERK
INSTRUCTOR
1
PRE-TEST
1
V→ V+1
2
STUDY GUIDE
2
S→ S+1
3
4
SUPPLEMENTARY INSTRUCTION
REMEDIAL INSTRUCTION
2
S→ S+1
8
2
S→ S+1
3
INDIVIDUAL GUIDANCE
5
HOMEWORK ASSIGNMENT
ADMINISTRATIVE ACTION
3
3
6
POST TEST
9
PRESCRIPTION
MARKS HOMEWORK
3
7
RE-TEST
1
V→ V+1
3
COMPLETES COURSE

## New York Institute of Technology

**PRE-TEST ROUTINE**

## SIM/AIMS

**PAGE ①**


STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
1
ISSUES PRE-TEST "V" A RESPONSE FORM
CONTROL
DOES PRE-TEST "V"
RESPONSE FORM
COLLECTS PRE-TEST A RESPONSE FORM
CONTROL
USE AIMS ?
YES
NO
RECORDS RESPONSE TRANSMITTAL
RECORDS INPUT DELIVERY
SCORES TEST
SCORES TEST
CIRCLES QUESTION NUMBER OF RESPONSE ERROR
MBO CROSS REF. FILE
STORES INFORMATION
GENERATES PRINTOUTS
RECORDS OUTPUT DELIVERY
EXEMPT ?
YES
V → V+1
1
CONTROL
NO
2

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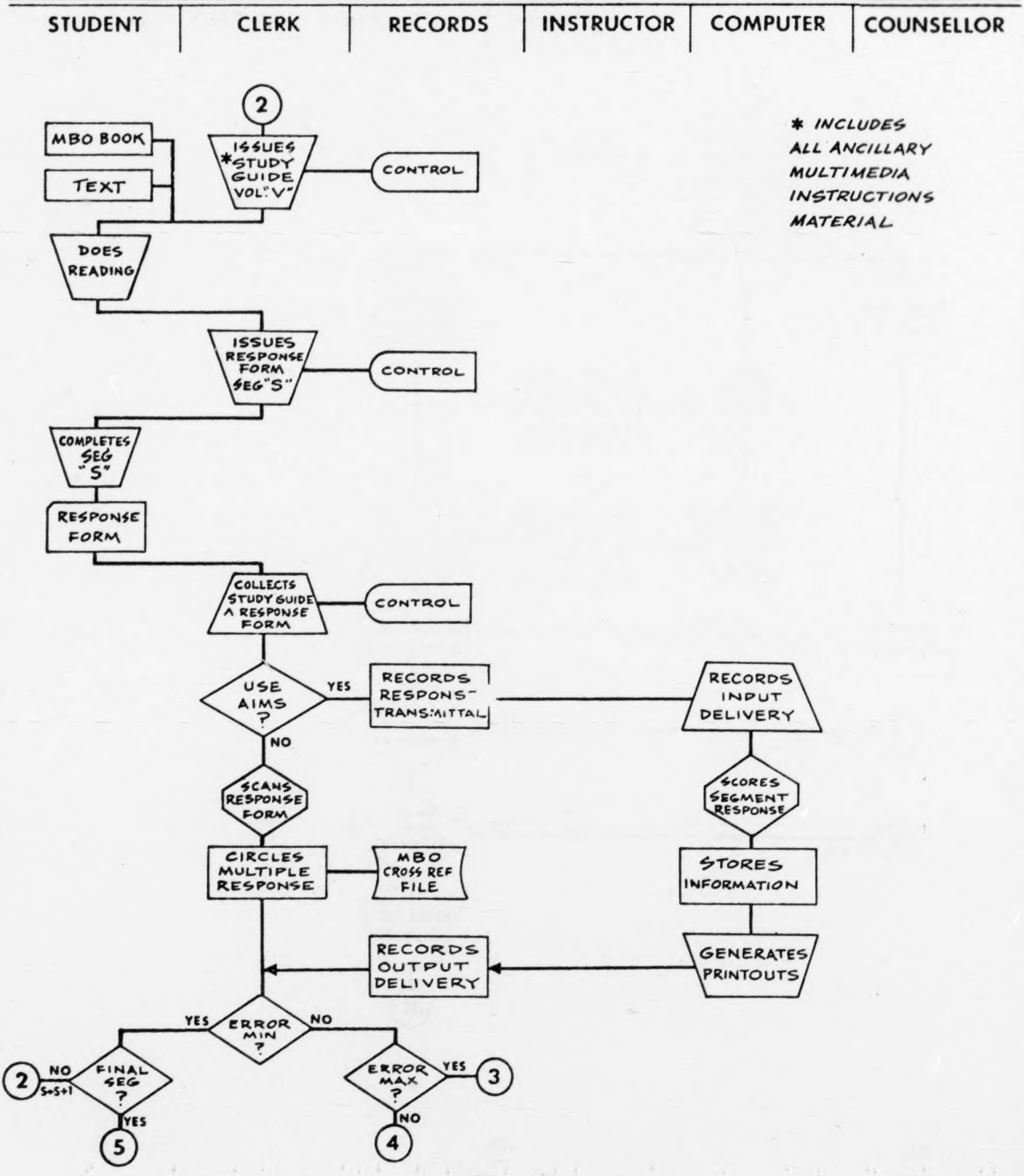
***STUDY GUIDE ROUTINE**

# SIM/AIMS

**PAGE ②**


STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
2
MBO BOOK
TEXT
ISSUES *STUDY GUIDE VOL."V"
CONTROL
DOES READING
ISSUES RESPONSE FORM SEG."S"
CONTROL
COMPLETES SEG "S"
RESPONSE FORM
COLLECTS STUDY GUIDE & RESPONSE FORM
CONTROL
USE AIMS ?
YES
NO
RECORDS RESPONS- TRANSMITTAL
RECORDS INPUT DELIVERY
SCANS RESPONSE FORM
SCORES SEGMENT RESPONSE
CIRCLES MULTIPLE RESPONSE
MBO CROSS REF FILE
STORES INFORMATION
RECORDS OUTPUT DELIVERY
GENERATES PRINTOUTS
ERROR MIN ?
YES
NO
FINAL SEG ?
NO
S←S+1
2
YES
5
ERROR MAX ?
YES
3
NO
4

* INCLUDES ALL ANCILLARY MULTIMEDIA INSTRUCTIONS MATERIAL

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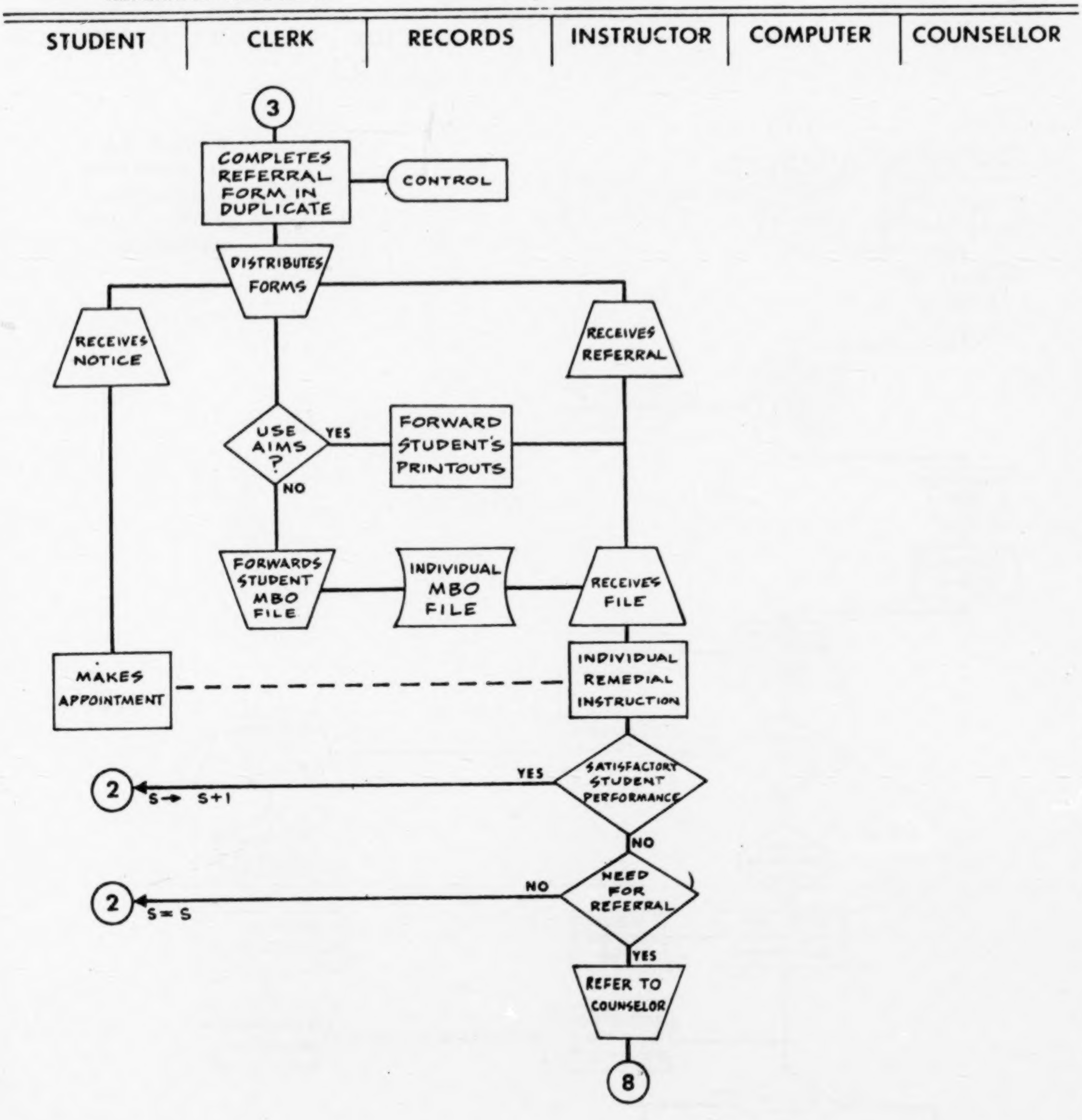
**REMEDIAL INSTRUCTION REFERRAL ROUTINE** SIM/AIMS PAGE ③


STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
3
COMPLETES REFERRAL FORM IN DUPLICATE
CONTROL
DISTRIBUTES FORMS
RECEIVES NOTICE
RECEIVES REFERRAL
USE AIMS ?
YES
NO
FORWARD STUDENT'S PRINTOUTS
FORWARDS STUDENT MBO FILE
INDIVIDUAL MBO FILE
RECEIVES FILE
MAKES APPOINTMENT
INDIVIDUAL REMEDIAL INSTRUCTION
SATISFACTORY STUDENT PERFORMANCE
YES
2
S→ S+1
NO
NEED FOR REFERRAL
NO
2
S = S
YES
REFER TO COUNSELOR
8

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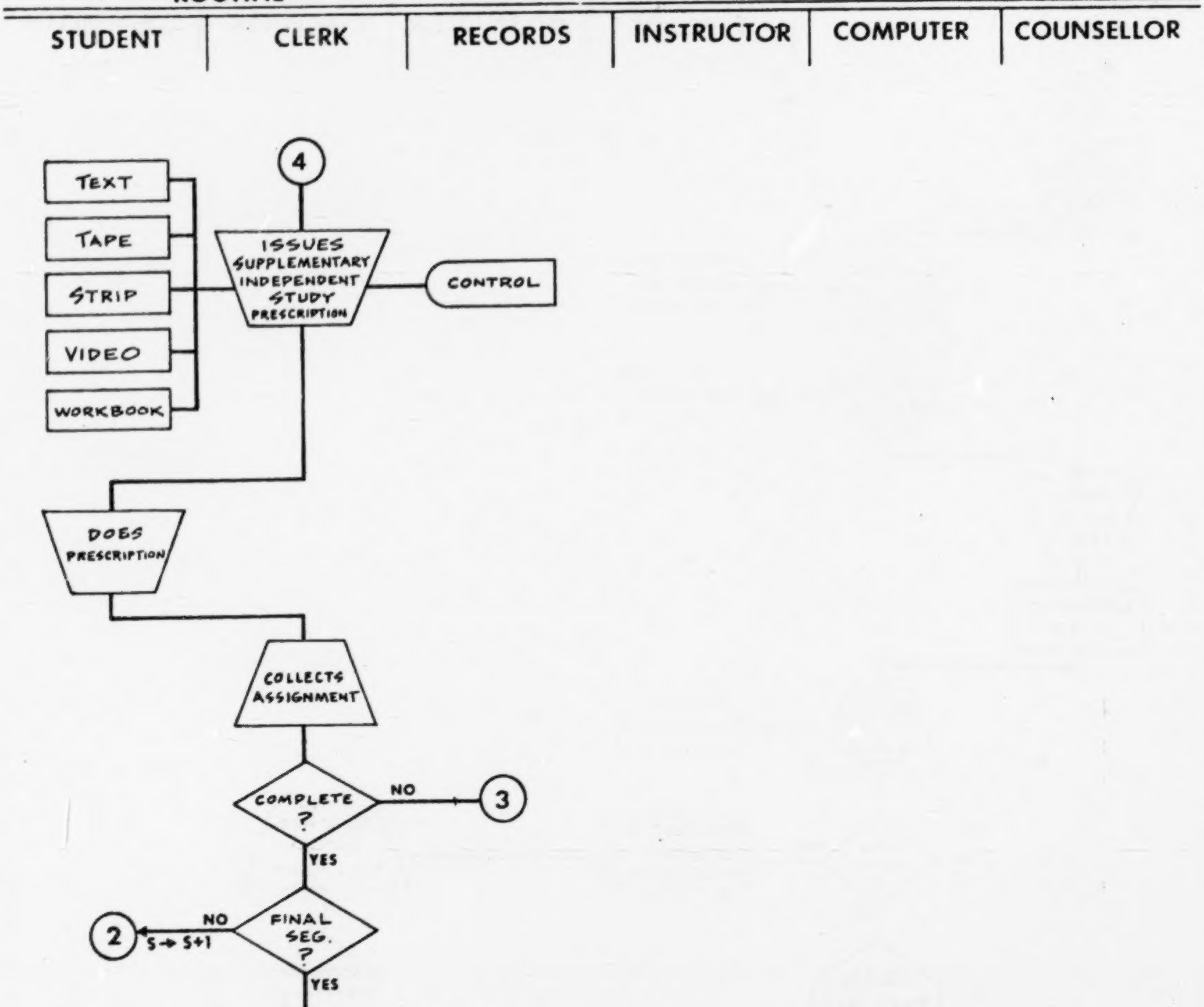
**SUPPLEMENTARY INDIVIDUAL INSTRUCTION ROUTINE**

## SIM/AIMS

**PAGE ④**

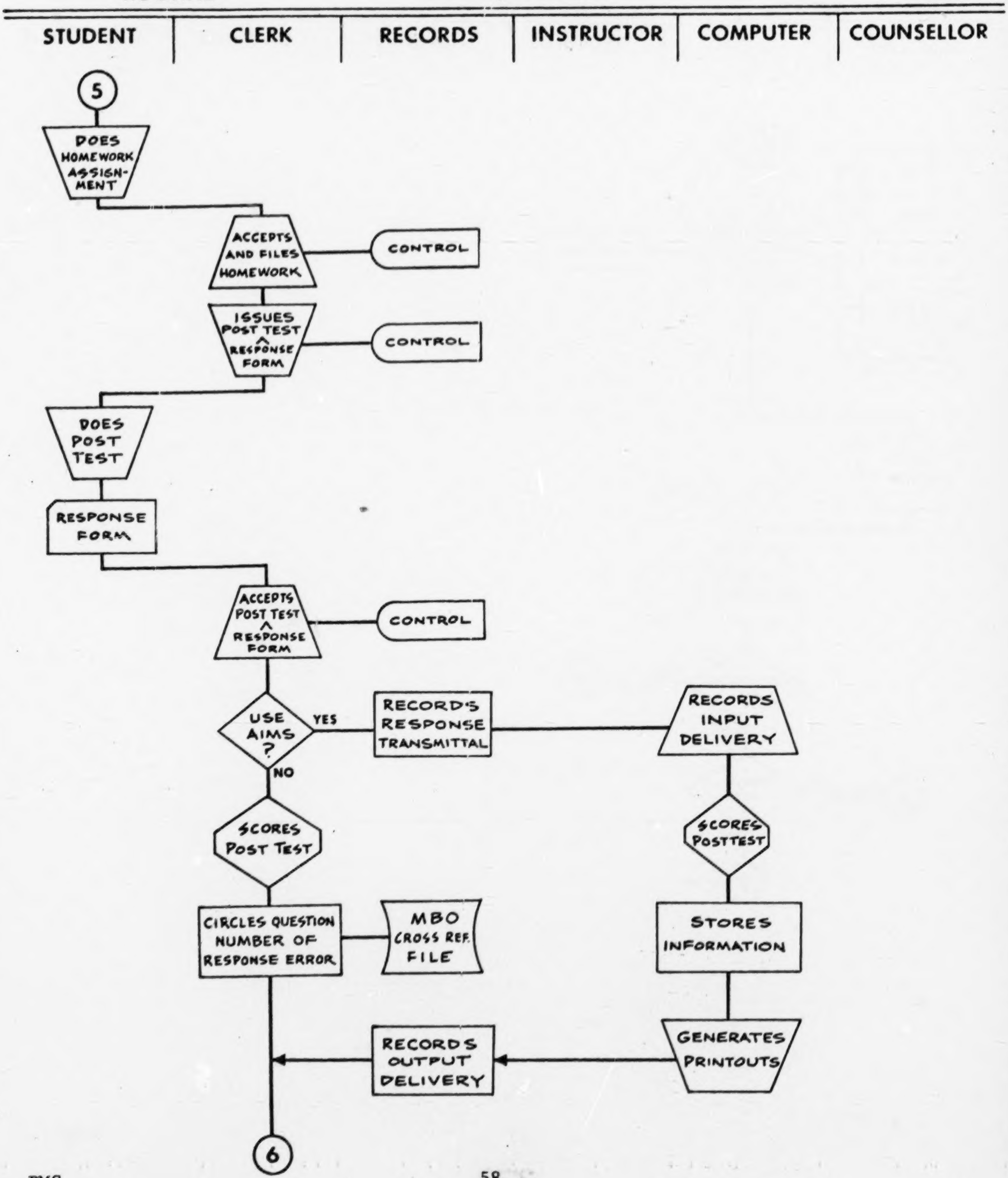

STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
4
TEXT
TAPE
STRIP
VIDEO
WORKBOOK
ISSUES SUPPLEMENTARY INDEPENDENT STUDY PRESCRIPTION
CONTROL
DOES PRESCRIPTION
COLLECTS ASSIGNMENT
COMPLETE ?
NO
3
YES
FINAL SEG. ?
NO
S → S+1
2
YES
5

# New York Institute of Technology

**END-VOLUME ROUTINE**

# SIM/AIMS

**PAGE ⑤**


STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
5
DOES HOMEWORK ASSIGNMENT
ACCEPTS AND FILES HOMEWORK
CONTROL
ISSUES POST TEST ^ RESPONSE FORM
CONTROL
DOES POST TEST
RESPONSE FORM
ACCEPTS POST TEST ^ RESPONSE FORM
CONTROL
USE AIMS ?
YES
NO
RECORDS RESPONSE TRANSMITTAL
RECORDS INPUT DELIVERY
SCORES POST TEST
SCORES POSTTEST
CIRCLES QUESTION NUMBER OF RESPONSE ERROR
MBO CROSS REF. FILE
STORES INFORMATION
GENERATES PRINTOUTS
RECORDS OUTPUT DELIVERY
6

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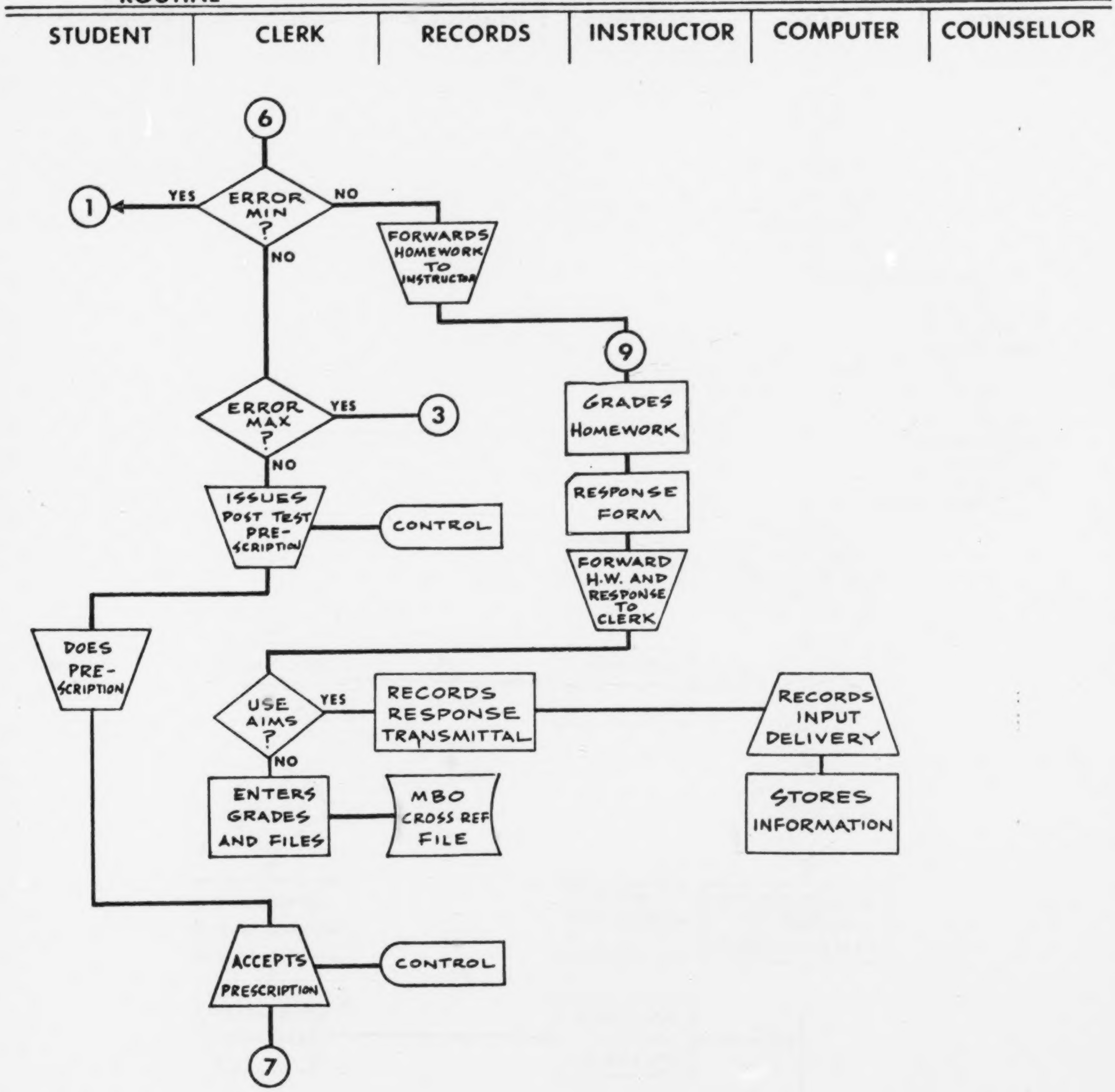
**POST TEST PRESCRIPTION ROUTINE**

## SIM/AIMS

**PAGE ⑥**


STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
6
ERROR MIN ?
YES
1
NO
FORWARDS HOMEWORK TO INSTRUCTOR
NO
9
GRADES HOMEWORK
RESPONSE FORM
FORWARD H.W. AND RESPONSE TO CLERK
ERROR MAX ?
YES
3
NO
ISSUES POST TEST PRE-SCRIPTION
CONTROL
DOES PRE-SCRIPTION
USE AIMS ?
YES
RECORDS RESPONSE TRANSMITTAL
RECORDS INPUT DELIVERY
STORES INFORMATION
NO
ENTERS GRADES AND FILES
MBO CROSS REF FILE
ACCEPTS PRESCRIPTION
CONTROL
7

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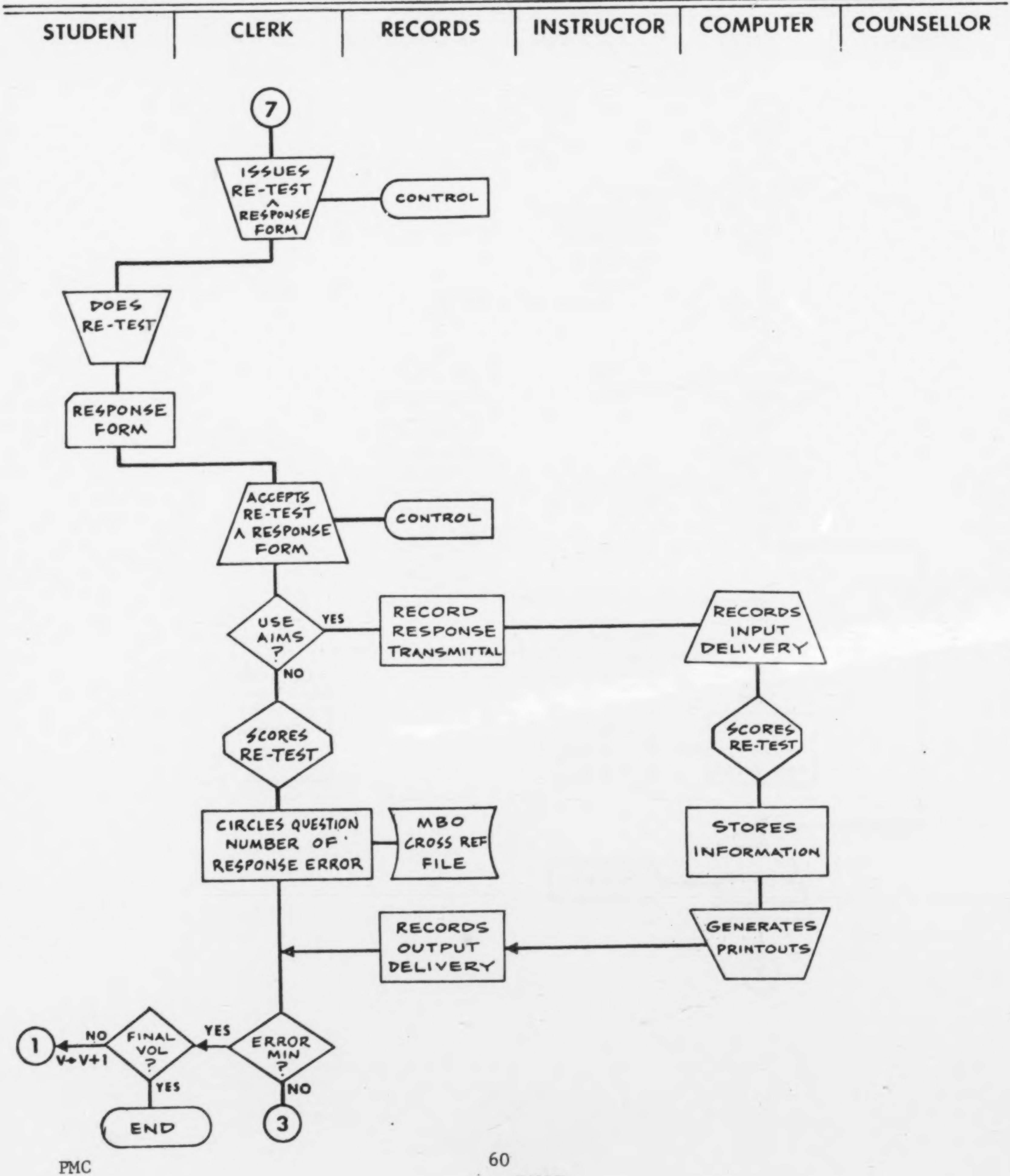
**RE-TEST ROUTINE**

# SIM/AIMS

**PAGE ⑦**


STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
7
ISSUES RE-TEST ^ RESPONSE FORM
CONTROL
DOES RE-TEST
RESPONSE FORM
ACCEPTS RE-TEST ^ RESPONSE FORM
CONTROL
USE AIMS ?
YES
NO
RECORD RESPONSE TRANSMITTAL
RECORDS INPUT DELIVERY
SCORES RE-TEST
SCORES RE-TEST
CIRCLES QUESTION NUMBER OF RESPONSE ERROR
MBO CROSS REF FILE
STORES INFORMATION
RECORDS OUTPUT DELIVERY
GENERATES PRINTOUTS
ERROR MIN ?
YES
NO
3
FINAL VOL ?
NO
V←V+1
1
YES
END

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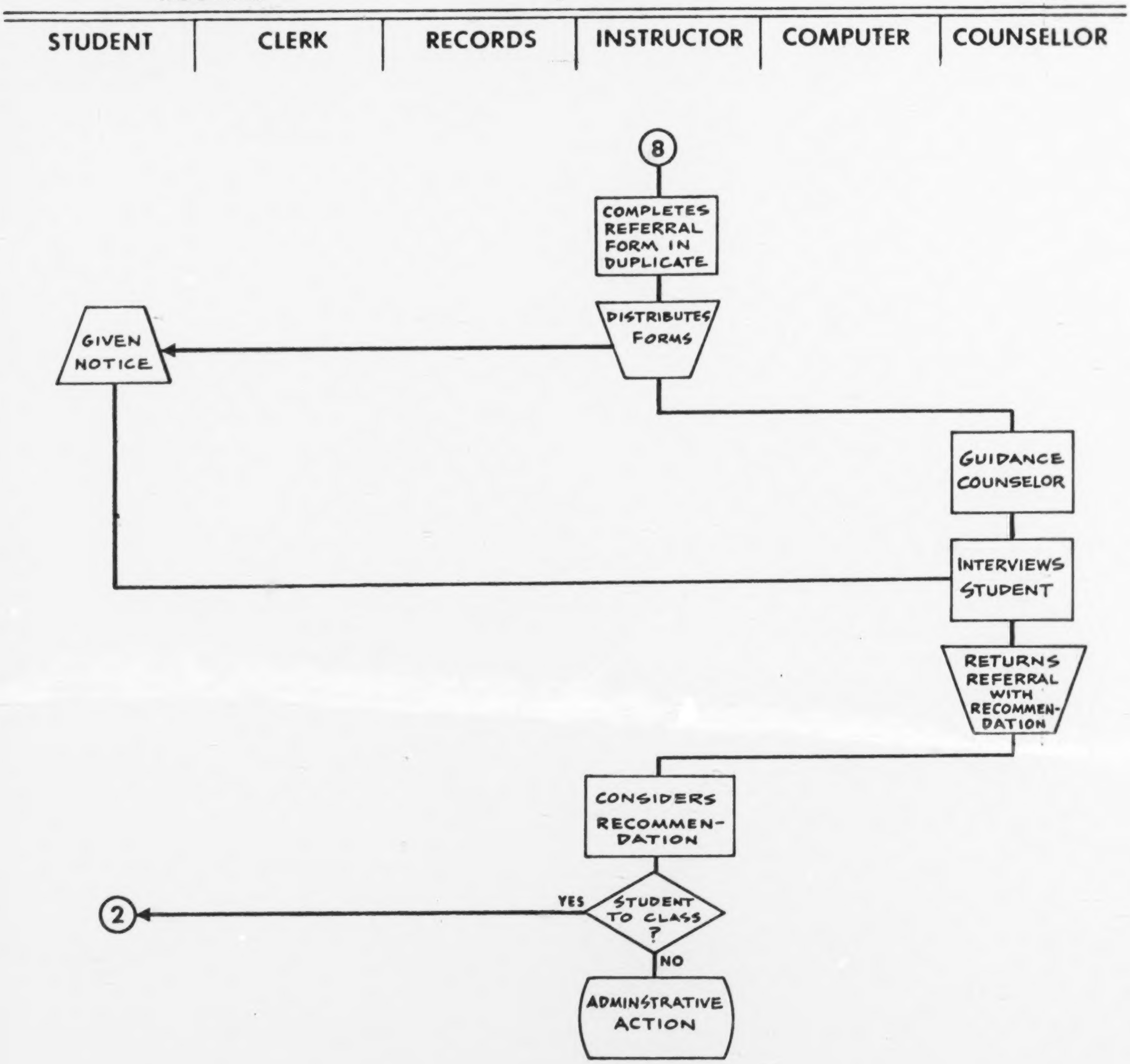
**GUIDANCE REFERRAL ROUTINE**

## *SIM/AIMS*

**PAGE ⑧**


STUDENT
CLERK
RECORDS
INSTRUCTOR
COMPUTER
COUNSELLOR
8
COMPLETES REFERRAL FORM IN DUPLICATE
DISTRIBUTES FORMS
GIVEN NOTICE
GUIDANCE COUNSELOR
INTERVIEWS STUDENT
RETURNS REFERRAL WITH RECOMMENDATION
CONSIDERS RECOMMENDATION
STUDENT TO CLASS ?
YES
NO
2
ADMINSTRATIVE ACTION

# 9

# ARTICULATED MULTIMEDIA PHYSICS

*A model computer managed, multimedia community college physics.*

# ARTICULATED MULTIMEDIA PHYSICS

## Table of Contents

I. ORIGIN OF COURSE MATERIALS .................... 1

II. STATUS .......................................... 5

III. COURSE DESCRIPTION ............................. 5

  a. General Objectives ......................... 5

  b. Scope of the Course ........................ 6

  c. Instructional Media ........................ 6

  d. Instructional Strategies ................... 7

  e. Analysis of Subject Matter ................. 8

IV. EVALUAION ....................................... 9

V. SUPPORTING MATERIAL ............................13

VI. DESIGN AND PROCEDURE HANDBOOK ..................16

## ARTICULATED MULTI-MEDIA PHYSICS

### Table of Figures

FIGURE 1 - Worksheet .......................7

FIGURE 2 - Film-Loops ......................8

FIGURE 3 - Student Requirements ...........14

FIGURE 4 - Instructor Requirements ........15

## ARTICULATED MULTIMEDIA PHYSICS

## I. ORIGIN OF COURSE MATERIALS

a. The programmed Study Guides, a sequence of 14 lessons, which now constitutes the core material of the Articulated Multimedia Physics (AMP) course were originally developed to meet the requirements of the secondary school syllabus in physics prepared by the New York State Department of Education in 1967.

b. The present Study Guides were initially written in a format suited to their reproduction on film to be used in the Autotutor Mark II teaching machine. The rights to this material were assigned to United States Industries, Inc., the designers and builders of the Autotutor.

c. This core material was published on film by United States Industries and made available throughout the nation in this form. The complete course contains 29 lessons in secondary school physics and completely covers the New York State Regents Syllabus.

d. The excellence of this material, its validated content, and its motivational character made it a natural choice upon which to base the Articulated Multimedia Physics course then being planned by the New York Institute of Technology.

e. It should be emphasized here that this plan called for a transitional course in physics which could serve at once as:

   1. a remedial activity for students who were having difficulty in their study of physics at the college level; and

   2. a preparatory course for entering students of the Institute who had either omitted physics in their secondary school education, or who had not met the required standards in this subject at the secondary level, yet wished to enter the field of technology in college.

f. To raise the level of the core material available in film format, the following interim procedure was adopted:

   1. The course designers studied the core material in the film with a view to selecting specific syllabus items upon which to base the enrichment and level escalation strategies to be adopted later.

   2. Colored signal markers were then hand-inserted on the applicable film frames to serve as triggers which would send the student out of the normal programmed track into the supplementary material described later.

   3. Selection of the signaled topics was based upon a number of considerations:

      a) Possibilities for enrichment--Certain subjects can be substantially enhanced in meaningfulness without raising the level beyond that desired by adding more in-depth material.

      b) Conceptual difficulty--Many topics in physics have a quality of abstractness that demands additional treatment by whatever strategies are available to aid in comprehension.

      c) Practical applicability--Aside from the pure scientific aspect of core physics material, many opportunities exist for adding and working over practical applications that will interest and motivate the student.

      d) Alternative approaches to problem solutions--Although the Study Guides contain illustrative problems and their step-by-step solutions, certain topics can be fruitfully expanded by considering additional problems and possibly alternative logical approaches to their solution.

      e) Topics for which single-concept loop films were readily available at the time that the expansion of the course was undertaken.

f. For each lesson a series of tape segments (audio cassette format) was prepared in master form and then replicated to produce 30 copies. The number of tape segments per lesson turned out to be approximately five. A lesson cassette is complete in itself, containing all the segments in "chronological" sequence as encountered by the student in working through the program.

g. Tape segments which related to single-concept films were produced to introduce the topic displayed in the film, and then to provide a voice-over section which was synchronized with the film as it was viewed by the student.

h. Each tape segment was accompanied by a worksheet containing instructions for use, auxiliary diagrams, sequences of equations where needed, and a group of criterion questions and/or problems relating to that topic as presented in the tape and/or film.

i. Plans were made at that time to record and evaluate the supplementary work by hand; for this reason, all criterion and diagnostic questions and problems were written for multiple-choice response.

j. When computer monitoring and adaptive feedback were later instituted, the selection of the multiple-choice mode was further justified.

k. The Autotutor presentation method was utilized for several classes during succeeding semesters. The experience gained from studying and evaluating student achievement led to the decision to eliminate the Autotutor machine from the self-paced individualized study procedure and replace it by programmed books containing identical material. The principal reasons for this decision stemmed from the following observations:

    1. Only 80 Autotutor machines were available. The number of students to be serviced simultaneously was estimated to exceed this number by a substantial margin.

    2. Student performance could not be gauged or measured with the desired precision for computer input. The error register in the machine could be compromised and the readings were therefore unreliable. Furthermore,

no indication could be obtained of the specific nature of the errors being made.

3. The heavy machines were necessarily fixed in location. Students expressed the desire to work on the programs at home as well as in the learning laboratory. This suggested the desirability of Study Guides in the form of bound volumes rather than bulky, fixed machines.

l. As a consequence, the entire content of the first 14 lessons was reprinted in the form of intrinsically programmed books, individually bound and titled so that they could be readily carried from place to place, and easily stored.

m. The worksheets for the tape segments and films were bound into the appropriate volumes; in addition, a homework section was added for each lesson so that the student might have the benefit of additional sourcebooks beside the programmed material.

n. A fail-proof signaling procedure was instituted for carrying the student out of the Study Guide, into the tapes and films, and back to the Study Guide to continue the lesson. The use of colored sheets helped the cueing process; the system was found to be quite workable. (A complete list of the audio-visuals is given on page 18-20 of this unit.)

o. The Articulated Multimedia Physics course in its present form is an outgrowth of empirical testing and constant revision over a period of several years. It is described in detail in the pages that follow; the AMP course, as a complete learning package is completely different from the original basic physics course prepared as core material and so used in the current version.

p. The Automated Instructional Management System (AIMS III) in use in physics at the present time incorporates a large number of correlated activities, many of which are common to Data Processing, the PMC, the Naval Academy course in physics, and the Articulated Multimedia Physics course. The various functions and outputs of the AIMS III system are described fully elsewhere.[1]

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[1] AIMS Version III System Manual

## II. STATUS

a. The Articulated Multimedia Physics Course (AMP) is a self-paced, individualized study program designed for computer management and developed through a Systems Analysis approach.

b. The AMP course, has been employed for instructional purposes in the New York Institute of Technology under the direction of the Special Education Department.

c. It has been transferred to the Physics Department of the New York Institute of Technology where it is now being used as a transitional course. Its general instructional objective is to prepare incoming students who do not immediately qualify for the three-semester general physics course given by the college. Its transitional nature enables it to fill the gap between standard secondary school physics and the level at which the course is taught at the Institute.

d. The AMP course has also been installed at Shaw University, North Carolina and Springfield Technical Community College, Massachusetts.

e. The fundamental management techniques are planned to lend themselves to statistical analysis of student performance with a view to empirical optimization of course content and course strategies.

f. The AMP course has been continually demonstrated at various meetings at New York Institute of Technology in which visiting educators at various levels have participated.

## III. COURSE DESCRIPTION

a. General Objectives

1. To serve as an individualized study program for above-normal ability secondary school students who wish to advance in the sciences while they are otherwise occupied with their regular schoolwork.

2. To be used by above-normal or normal ability secondary school students to perform required

"make-up" work after a prolonged absence from school.

3. To provide adequate transitional material in physics for students who have either not had the subject matter previously, or who have not achieved the necessary level of accomplishment that would qualify them for general college physics.

b. Scope of the Course

1. The material now in final form includes the range of information and skills beginning with significant figures, scientific notation, and physical measurement through mechanics, include statics, kinematics, dynamics, gravitation, circular motion, energy and work, the conservation principles, and basic thermodynamics.

2. Material already written in final form to which is to be added the desired audiovisuals and computer management mechanism includes geometric and physical optics, electricity, magnetism, wave motion, sound, and modern physical theory.

3. The AMP course in its present form as a transitional course requires a single semester of student participation involving all of the audiovisuals and other support materials. Students are required to devote at least one hour per day to the study material and one hour per day to homework assignments.

c. Instructional Media

1. The major portion of the content is presented in the form of an intrinsically programmed sequence containing 14 volumes which include both primary and secondary branching loops. These volumes are identified as AMP References 1-14.

2. Provision is made for monitoring progress through each of these Study Guides by means of the SIM/AIMS Mode.

3. Each Study Guide is accompanied by five to eight tape segments (audio) which present additional or clarifying discussions of the content. The list

of audio tape titles is included in this report as Appendix . Each tape segment is coordinated with a worksheet and requires frequent student responses in written form. The worksheets are also designed for computer grading, recording, and remediation procedures. (See Fig. 1, below.)

AMP LESSON 4 TAPE SEGMENT 1

WORKSHEET

Please listen carefully to tape segment 1 for this lesson before starting this Worksheet.

Your answer selections for the questions that appear below are to be indicated on the mark sense sheet for this lesson in the usual way.

1. When a scalar quantity is multiplied by a vector quantity, the product is always a vector quantity. Which one of the following products is a vector quantity?

A time x temperature.
B mass x time.
C mass x velocity.
D mass x temperature.
E none of the above is a vector quantity.

WORKSHEET

Fig. 1

d. Instructional Strategies

1. AMP Reference 15, entitled ARTICULATED MULTIMEDIA PHYSICS - Design and Procedure, provides a complete description of the instructional modes and strategies used in the course.

2. Student responses are now made on mark-sense forms intended for optical scanning rather than on punch cards as originally planned.

e. Analysis of Subject Matter

1. The syllabus is based on many of the recommendations of the Physical Science Study Committee as set forth in the text published by Heath and Company, as well as material outlined in the text entitled Physics: Fundamentals and Frontiers, by Stollberg and Hill (Houghton-Mifflin).

2. The level of the subject matter contained in the 14 Study Guides approximates that of the New York State Regents Syllabus in Physics for Secondary Schools.

3. All of the individual subject areas covered in the Study Guides have been increased in depth by the addition of tape segments and single concept films. It should be noted that all of the single concept films are rated for college use. The same is true of the accompanying voice-over tape segments.

4. Frequent use is made of commercially available single-concept films, on silent 8 mm cassette format. Each of these films is provided with a voice-over audio cassette, synchronized by the student to the film. The voice-over presentations in narrative form increase the educational value of the films manyfold. (See Fig. 2, below.)

EALING FILM-LOOPS

| | | |
|---|---|---|
| 18-132/a | 4 | THE VELOCITY VECTOR |
| 80-214 | 8a | INERTIAL FORCES: CENTRIPETAL ACCELERATION |
| 80-213 | 8b | INERTIAL FORCES: TRANSLATIONAL ACCELERATION |
| 80-274 | 9a | NEWTON'S THIRD LAW |
| 80-212 | 9b | MEASUREMENT OF "G"<br>THE CAVENDISH EXPERIMENT |
| 80-254 | 10 | VELOCITY & ACCELERATION IN CIRCULAR MOTION |
| 80-277 | 11a | CONSERVATION OF MOMENTUM<br>ELASTIC COLLISIONS |
| 80-275 | 11b | CONSERVATION OF MOMENTUM<br>INELASTIC COLLISIONS |
| 80-276 | 12 | CONSERVATION OF ENERGY |

Fig. 2 FILM-LOOPS

5. Each volume is matched to a posttest intended for computer grading and remediation.

6. Each volume is accompanied by homework questions and problems graded by the instructor, and entered into the management system by special code explained in the Design and Procedure Handbook accompanying this report as Reference 15.

## IV. EVALUATION

a. Classification of Objectives: behavioral objectives for a discipline such as physics may be classified functionally to good advantage with respect to computer management. A given objective may have as its outcome behavior which indicates one or more of the following:

1. that the learner has committed to memory an essential "tool fact" and can reproduce this fact at will;

2. that the learner understands and can reproduce a principle or law of general nature in physics;

3. that the learner can apply any single principle, law, or other concept to the solution of a single step problem, descriptive or numerical, in which direct substitution is required;

4. that the learner possesses the requisite basis mathematical skills to convert an equation or proportion on the desired level to a form that is usable in solving a single-step problem in which direct substitution is not possible as in the following example:

   "Given that the centripetal force $F = mv^2/r$, find the tangential velocity of a body in circular motion in which F, m, and r are known."

   This requires the ability to solve the equation literally (symbolically) for v;

5. that the learner can make decisions involving the order and handling of sequential steps in the solution of a multistep problem, descriptive or numerical, selecting and evaluating the required principles;

6. that the learner can make decisions which permit him to discard false clues and select those factors which have a bearing on the problem at hand.

b. Attention is called to numbers 5 and 6 above. It is the conclusion of the course developing team that decision-making behavioral objectives in physics represent the essence of a true education in the discipline. Student success in such objectives demands that appropriate attitudes and methods of attack be developed as gradually as necessary for each individual learner. It is in this area where self-pacing plays its most important role.

c. Decision-making objectives may be classified in various ways. For physics, the following objectives have been at least partially validated.

Given a multistep problem, the learner must be able to:

1. list the physical relationships which have a bearing on the solution;

2. discriminate between relevant and irrevelant data and discard the latter;

3. organize relevant data and applicable relationships in logical order for subsequent handling;

4. fuse data and relationships sequentially to arrive at the correct result.

d. Modification of Initial Behavioral Objectives

1. Initial behavioral objectives are normally structured by reference to selected texts, the results of educational experiments and reports (e.g., PSSC, Physical Science Study Committee), syllabus trends, industrial trends, and changing college requirements.

2. The objectives are then sorted by categories (see sections IVa, b, and c above). Sorting by category provides a natural means to check for omissions and repetitions, particularly the former. The objectives for each topic (e.g., the Law of Universal Gravitation) are examined to determine if samples in every classification have been included.

3. A matrix is then set up in which sub-topics appear along one axis and categories along the other. Each cell of the matrix is then examined for omissions and repetitions.

e. Empirical Pretesting of Objectives

   1. In this phase, a series of questions which relate to the objectives in a given topic are intuitively generated by a capable, experienced teaching team. There is at least one question per objective, the question being phrased to ascertain the level of the student's background.

   2. The objectives are then refined in two basic ways:

      a) questions are revised to eliminate difficulties which prevent them from measuring the behavior they were intended to measure;

      b) objectives are discarded when the data shows that they represent material already learned by the student population.

   3. The students used in this type of validation scheme are those who have previously studied physics at the secondary school level and who have been exposed to integrated high school mathematics involving fundamental algebra, geometry, and the elements of trigonometry.

   4. Although it is recognized that heterogeneity of previous achievement cannot be avoided, it is held that such pretesting can identify objectives which may be eliminated entirely or relegated to homestudy for the purpose of releasing time for more essential classroom activities.

   5. A complete listing of the coded Measurable Behavioral Objectives List is presented as AMP Reference 16.

f. Empirical Design of Instructional Material[2]

   1. Instructional materials are first selected on the basis of experimental studies (i.e., PSSC, Harvard

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[2] The reader is referred to the Empirical Course Development Model (EDM); NYIT.

Project Physics and State Syllabi), and on the basis of the experience of the structuring staff as teachers of the subject, keeping in mind the ultimate course objectives, i.e., whether the course is terminal or is to lead to further work in the field.

2. Media are selected and sequenced on the basis of their natural application to the subtopic at hand. The Study Guide and associated textbooks represent the source material for all phases of the work; audio tapes, worksheets, films with and without voice-over, and special diagrams are supportive material, inserted as indicated by the following criteria:

   a) to provide enrichment;

   b) to clarify explanations of concepts that are considered more difficult than others normally encountered in the work;

   c) to upgrade the level of the material from that of the secondary school to the transitional nature of the course;

   d) to stimulate interest;

   e) to reinforce the printed program especially when motion is involved in the topic;

   f) to provide addtional practice in problem-solving.

3. Each supportive item is monitored in all details to provide information which subsequently is used to revise and improve the Study Guides, the audio-visual worksheets, the progress tests, the audio tapes, and the films. The same data obtained by the monitoring process is, of course, applied to the techniques of student management as described in the exposition of the AIMS III system.

4. The posttests (or progress tests) are similarly monitored to make possible evaluation of the total course material and to provide the information required for remediation.

g. Remediation Procedures

1. Where the monitoring process indicates the need for remediation, instructions are given to the individual student under the options in the SIM/AIMS Mode. These instructions may include one or more of the following directions:

   a) Additional reading in selected texts other than the one used as a required source;

   b) Repetition of relevant sections of the program that has just been completed;

   c) Remedial tapes and films;

   d) Tutorial sessions with the instructor.

## V. SUPPORTING MATERIAL

a. The supporting material lists indicate the software and hardware needed by each student, and the software needed by each instructor.

b. The STUDENT list (Fig. 3) has been divided into three sections to differentiate between the types of supporting materials in terms of:

   1. Instruction Program Software;

   2. Instruction Program Hardware;

   3. Testing Program Software.

c. The INSTRUCTOR list (Fig. 4) has been divided for similar reasons into the categories:

   1. Instruction Program Software;

   2. Testing Program Software;

   3. Course Operation Software.

d. The need for mechanical handling and periodic replacement of the supporting material is indicated for each item on each list by means of a code as follows:

   1. Code 0: reusable

NYIT
AMP

OPERATING REQUIREMENTS
NEEDED BY STUDENT:

USE CODE:
O re-usable
X expendable
* security required
( ) can be shared

| ITEM NO. | USE CODE | | NO. REQUIRED |
|---|---|---|---|
| INSTRUCTION PROGRAM SOFTWARE | | | |
| 1. | O | TEXT:<br>Physics-Its Methods and Meanings Taffel;-(Allyn and Bacon) | (1) |
| 2. | O | MBO BOOK | (1) |
| 3. | O | STUDY GUIDES | 1 set of 14 |
| 4. | O | STUDY GUIDE | |
| | | Response Form | 1 set of 26 |
| | | Form #6006 (If AIMS) | 1 set of 26 |
| 5. | O | HOMEWORK ASSIGNMENT | 1 set of 14 |
| 6. | X | CONTROL SHEET | 2 |
| 7. | O | SINGLE CONCEPT FILM LOOPS | (1 set of 9) |
| 8. | O | AUDIO TAPE CASSETTES | (1 set of 14) |
| INSTRUCTION PROGRAM HARDWARE | | | |
| 9. | (O) | AUDIO TAPE CASSETTE PLAYBACK MACHINE | (1) |
| 10. | (O) | FILM PROJECTOR | (1) |
| 11. | (O) | TELESCREEN | (1) |
| 12. | O | PEN | 1 |
| TESTING PROGRAM | | | |
| 13. | *O | POST TEST | 1 set of 13 |
| 14. | *O | FINAL EXAMINATION | 1 |
| 15. | X | TEST RESPONSE FORMS #1451 | 14 |
| 16. | X | (If AIMS) #6007 | 14 |

Requirements Fig. 3 Student

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AMP

OPERATING REQUIREMENTS

NEEDED BY INSTRUCTOR:

USE CODE:
- 0 re-usable
- X expendable
- * security required

| ITEM NO. | USE CODE | | NO. REQUIRED |
|---|---|---|---|
| INSTRUCTION PROGRAM SOFTWARE | | | |
| 1. | 0 | TEXT:<br>Physics-Its Methods and Meanings Taffel;-<br>(Allyn and Bacon) | 1 |
| 2. | 0 | HANDBOOK | 1 |
| 3. | 0 | MBO BOOK | 1 |
| 4. | 0 | STUDY GUIDES | 1 set of 14 |
| 5. | *0 | Visible Ans. Matrix | 1 set of 14 |
| 6. | 0 | READING ASSIGNMENT | 1 set of 14 |
| TESTING PROGRAM SOFTWARE | | | |
| 7. | *0 | POST TEST | 1 set of 13 |
| 8. | *0 | ANSWER KEY | 1 set of 13 |
| 9. | *0 | FINAL EXAMINATION | 1 |
| 10. | *0 | ANSWER KEY | 1 |
| 11. | *0 | A.V. ANSWER KEY | 1 set of 14 |
| 12. | 0 | HOMEWORK ASSIGNMENT | 1 set of 14 |
| 13. | *0 | ANSWER KEY | 1 set of 14 |
| COURSE OPERATION SOFTWARE | | | |
| 14. | X | CONTROL SHEET | 2 per student |
| 15. | X | MBO CROSS REFERENCE LIST | 1 set per student |
| 16. | 0 | ERRATA SHEET | 1 |

Requirements Fig. 4 Instructor

2. Code X: expendable
3. Code *: requires security measures
4. Code ( ): may be shared during session

e. A complete set of the support material is on file at the Learning Management Resource Center of the New York Institute of Technology, Old Westbury, New York.

Reference 1 - 14 AMP Study Guide Volumes

15 Design and Procedure Handbook

16 Set of 14 Audio tapes

17 Set of 9 Film-Loops

18 All Hardware

f. It is to be understood that the hardware requirements are flexible to the extent that tape cassettes may be prepared in any form so that the playback may be selected to match; similarly, the single concept loops may be either regular 8 mm or super-8 with matching projectors, or the newer super-8 rapid rewind cartridges; or video cassettes.

## VI. DESIGN AND PROCEDURE HANDBOOK

The Design and Procedure Handbook (AMP Reference 19) combines the features of a course designer's sourcebook and an instruction manual for course operation. Its organizational description follows:

a. The General Course Description provides the rationales for the course, the level for which the course is designed, its length and content, and the general strategies to be used in the instructional and testing programs.

b. The Course Elements section deals with the nature and selection of the measurable behavioral objectives and general instructional sources.

c. The section entitled Elements of Computer Management provides information relative to computer input, computer data output, media designations, skill categories, and types of computer input forms. The Handbook discusses the use of IBM punchcards. In recent semesters of course operation, mark-sense forms which permit optical scanning have been substituted for the cards to improve accuracy and speed of handling.

d. The Sequence for Software Preparation section deals with both general and specific suggestions for sequencing the preparation of software.

e. The Coordinator's Responsibilities are given in detail in a separate section, on page 10.

f. The Appendix of the Handbook contains models of forms used in course structuring.

## ARTICULATED MULTIMEDIA PHYSICS

### Audio-visual Tapes and Films

| | | |
|---|---|---|
| Lesson 1: | Tape 0: | Introduction to the course |
| | Tape 1: | The Development of the Standard Meter |
| | Tape 2: | The Meaning of the Reciprocal of a Number |
| | Tape 3: | Time Standards |
| | Tape 4: | Mass and Weight - A Baseball Game on the Moon |
| | Tape 5: | Eliminating Parallax in Reading Instruments |
| Lesson 2: | Tape 6: | Expanding on the Subject of Significant Figures |
| | Tape 7: | Measuring the Length of a Dollar Bill |
| | Tape 8: | A special Convention for Significant Figures |
| | Tape 9: | The Value of Scientific Notation |
| | Tape 10: | A Number Raised to the Zero Power |
| Lesson 3: | Tape 11: | Practice in Arithmetic |
| | Tape 12: | Higher Powers in Scientific Notation |
| | Tape 13: | The Use of Half-Power Notation for Square Root |
| | Tape 14: | Subtraction of Numbers with Attention to Significant Figures |
| | Tape 15: | Orders of Magnitude |
| Lesson 4: | Tape 16: | The Difference Between a Vector and a Scalar |
| | Tape 17: | Vectors at Angles Larger than 90 Degrees |
| | Tape 18: | THE VELOCITY VECTOR - Single concept film, voice over |
| | Tape 19: | Boat Crossing a Stream - Vector Solution |
| Lesson 5: | Tape 20: | Selecting Cartesian Axes for Dependent and Independent Variables |
| | Tape 21: | A Complex Speed-Time Graph Analysis |
| | Tape 22: | Analyses of Distance-Time Graphs |
| | Tape 23: | The Significance of Changing Slopes in Distance-Time Graphs -- Discontinuities |
| | Tape 24: | Graphs of Motion for a Ball Ascending and Descending an Inclided Plane |
| Lesson 6: | Tape 25: | Using Direct Proportions to Calculate How Many Earths could Fit into One Sun |
| | Tape 26: | Probing the Meaning of "g" (Gravitational Acceleration) |
| | Tape 27: | Deceleration of a Freely Rising Body and Acceleration of the Same Body in Free Fall |
| | Tape 28: | Acceleration of a Bullet in the Barrel of a Rifle |

| | | |
|---|---|---|
| Lesson 7: | Tape 29: | Review of Vector Problems |
| | Tape 30: | The Concept of Dynamic Equilibrium |
| | Tape 31: | Vectors for a Taut Clothes-line |
| | Tape 32: | Trigonometric Solution of the Boom Problem |
| Lesson 8: | Tape 33: | Troublesome Experiments with the Inertia of Bodies |
| | Tape 34: | The Fictional Nature of Centrifugal Force; THE ROTOR - Single concept film, voice over |
| | Tape 35: | An Extended Discussion of Newton's Second Law |
| | Tape 36: | An Analysis of Terminal Velocity |
| | Tape 37: | INERTIA FORCES - TRANSLATIONAL EQUILIBRIUM - Single concept film, voice over |
| Lesson 9: | Tape 38: | NEWTON'S THIRD LAW - Single concept film, voice over |
| | Tape 39: | The Law of Gravitation |
| | Tape 40: | THE CAVENDISH EXPERIMENT - Single concept film, voice over |
| | Tape 41: | Discussion of Acceleration in Free Fall and its Independence of Mass |
| Lesson 10: | Tape 42: | The Concept of Frames of Reference |
| | Tape 43: | Motion of a Particle in a Horizontal Circle |
| | Tape 44: | Centripetal Force on the Planets of the Solar System |
| | Tape 45: | Centripetal Force on Charged Subatomic Particles |
| | Tape 46: | Analysis of a Solar System Table for Orbital Velocities |
| | Tape 47: | Central Forces on an Object Resting on a Rotating Phonograph Turntable |
| | Tape 48: | VELOCITY AND ACCELERATION IN CIRCULAR MOTION- Single concept film, voice over |
| Lesson 11: | Tape 49: | Impulse and Momentum in a Baseball Game |
| | Tape 50: | Impulse and Momentum Applied to Hammer Driving a Nail |
| | Tape 51: | Impulse and Momentum Applied to Ball Bounding from a Wall |
| | Tape 52: | CONSERVATION OF MOMENTUM - ELASTIC COLLISIONS Single concept film, voice over |
| | Tape 53: | CONSERVATION OF MOMENTUM - INELASTIC COLLISIONS Single concept film, voice over |
| Lesson 12: | Tape 54: | Combining Proportions in Physics |
| | Tape 55: | Application of Trigonometry to Work Problems |
| | Tape 56: | The Work Required to Stop a Moving Mass |
| | Tape 57: | Independence of Work Done in a Conservative Field with Respect to Path of Displacement |
| | Tape 58: | CONSERVATION OF ENERGY - Single concept film, voice over |

| | | |
|---|---|---|
| Lesson 13: | Tape 59: | Energy Transofrmation in Inelastic Collisions |
| | Tape 60: | Thermal Molecular Motion |
| | Tape 61: | Centigrade and Fahrenheit Temperature Conversions |
| | Tape 62: | Work Done in Compressing a Gas |
| | Tape 63: | The Mechanical Equivalent of Heat |
| | Tape 64: | The Specific Heat of a Substance |
| Lesson 14: | Tape 65: | Characteristics of an Ideal Gas |
| | Tape 66: | Normal Atmospheric Pressure in Various Unit Systems |
| | Tape 67: | Combining the Laws of Boyle and Charles |
| | Tape 68: | Limitations of the Ideal Gas Model |
| | Tape 69: | Farewell Message |

# 10

# SYSTEM FOR PUPIL AND PROGRAM EVALUATION AND DESIGN

*A major derivative and expansion of the original management system. This generalization subsumes the Adaptive Instructional Management System and refers to a major dissemination of and use of the project. This project was originally developed within the New York State Education Department under the supervision of Dr. Robert Reilly. The N.Y.I.T. system was adapted to meet the New York State Education Department system requirements.*

# SYSTEM FOR PUPIL AND PROGRAM EVALUATION AND DESIGN†

## Table of Contents

I. INTRODUCTION .................................. 1

II. SPECIFIC PARTS OF THE SPPED .................. 4

III. EVALUATION MODELS ............................ 8

IV. TRAINING ..................................... 10

V. ORGANIZATIONAL STRUCTURE ..................... 12

VI. DATA PROCESSING .............................. 15

VII. FUTURE DEVELOPMENTS .......................... 15

VIII. LIMITATIONS .................................. 17

DISSEMINATION AND VISITATIONS ................ 18

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SYSTEM FOR PUPIL AND PROGRAM
EVALUATION AND DESIGN

Table of Figures

FIGURE 1 ....................................1

FIGURE 2 - Test Period .....................2

FIGURE 3 - Unit One ........................3

FIGURE 4 ...................................5

FIGURE 5 - TO 61326 ........................8

FIGURE 6 - TO 61326 for 6th
Graders ........................9

FIGURE 7 - CO's for 6th Grade
mathematics ...................9

FIGURE 8 - Staffing structure for
SPPED ........................13

FIGURE 9 ..................................16

## I. INTRODUCTION

SPPED is a development project which is applying available computer technology to many of the outstanding problems of managing both instruction and the progress of individuals in the schools. Components of the SPPED were initially determined by asking various segments of the educational community the basic question: Given that means could be found to provide the basic supporting information, what do you feel are the most important educational decisions you would want to make?

On this basis, our investigators were eventually led to formulate lengthy lists of decisions for various educational audiences. These were then validated many times over in presentations and in practice in applying early models of parts of SPPED. For example, the researchers found that teachers were much concerned with decisions associated with their programs in such contexts as:

1. Should some parts of an instructional unit be re-taught for all? Most? A few?

2. At the outset of a unit of instruction, are there components which are effectively learned and should not be taught?

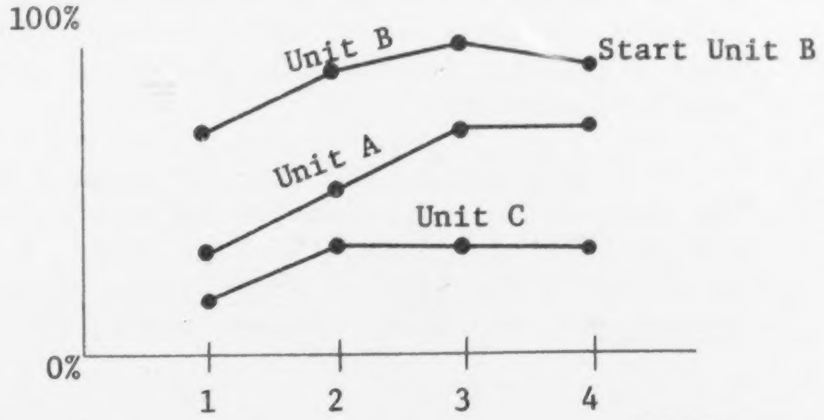
3. Should different instructional unit components receive different levels of emphasis?

These concerns indicated a need for a tool which would allow teachers to continuously adjust a program in relation to a given population of students. Such a tool was developed and implemented under the name, Comprehensive Achievement Monitoring, known more briefly as CAM. Project CAM placed in the hands of teachers and students an important new management tool which provided the basis for continuous and long-term refinement of instructional programs. For example, when teachers wanted information which would allow them to adjust a program prior to teaching, the CAM system delivered computer generated data, similar to the following:

A. Previous Units

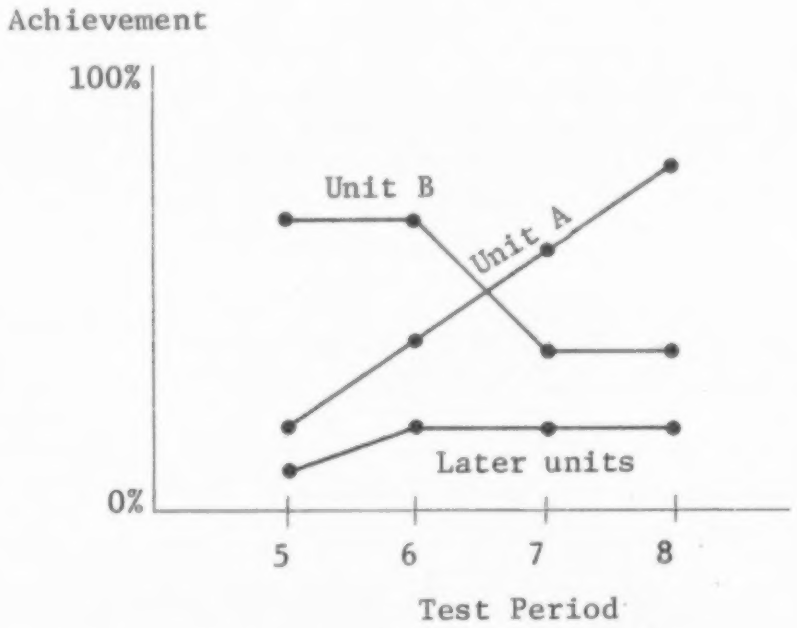
B. Next Unit

C. Later Units



This shows that unit B was already at a high level of achievement prior to instruction. Without going into detail as to how the CAM procedure works, we should point out here that this useful information is derived at the cost of testing only a small sample of students (perhaps 5 to 20% of students in the course), for roughly one-half hour.

This example shows how CAM can enable a teacher to make a certain type of mid-course correction, and extensively reduce the amount of instructional time given over to a segment of a course. At later points in time, the CAM system further informs the teacher of long-term success for unit B:



Here the teacher has made a successful correction for A (previously taught) and now finds B deteriorating, a not uncommon finding where units are highly related and maximally interfering.

Once CAM was installed in a given school, teachers initiated a variety of actions which allowed them to improve instruction not only in relation to large program segments, such as a unit, but also finer program components dealing with single important objectives. Shortly, teachers experienced in CAM turned their attentions to classes of decisions associated with individual students and modifications of local programs in the direction of individualized instruction. Further work on the SPPED Project then led to the development of a computerized mastery testing system, sufficiently generalized to support most models of instruction, including group paced and individualized learning.

Applications of CAM and mastery testing, in turn, showed the need for a comprehensive stock of instructional objectives and test items. Thus, the initiation of the SPPED bank, referred to as BOIR, for Bank of Objectives, Items, and Instructional Resources. The BOIR, without doubt, fulfills a broadly based need of educators for the basic tools which allow one to build an instructional management system. Otherwise, educators are faced with the arduous and expensive task of locally formulating thousands of goal statements.

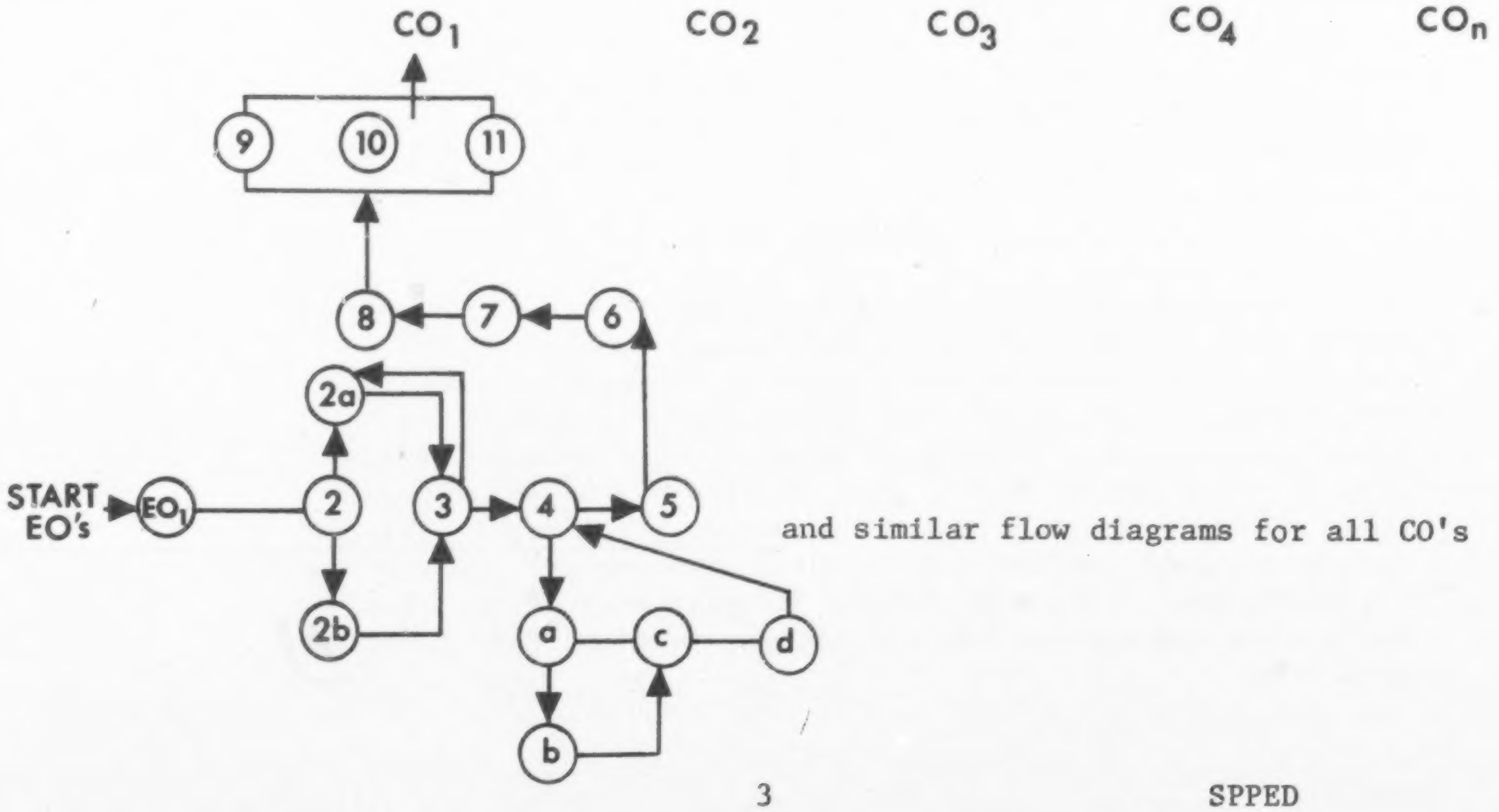
The BOIR and mastery testing program (formerly called AIMS) directly support mastery testing at two levels, corresponding to types of objectives, included among other types in the bank:

> Course Objective--a major goal statement describing an action to be performed by a student in a given course or at a given point in time.
>
> Enabling Objective--a component of a course objective, not meaningful in itself, but is part of the action enabling performance of the course objective.

For example, a course objective in mathematics might describe a generalized capability to perform the division algorithm with number problems of a certain type; e.g., up to 6-digit divisors, 10-digit dividends, etc., and further state that six such problems are to be completed with at least 90% accuracy in 20 minutes. Enabling objectives for this capability would include lower level capabilities such as: rapid calculation in relation to multiplication, addition, and subtraction of whole numbers, order of operations, etc.

Depending on the local model, one might use course objectives (CO's) enabling objectives, (EO's) and related test items for mastery testing as follows:

UNIT ONE



and similar flow diagrams for all CO's

In this example, the student is pretested for mastery on all CO's in the unit and then is assigned to instruction for those not mastered (start with EO1 for CO1). He proceeds through the sequence of EO's for $CO_1$, is post tested, proceeds similarly to the next segments of the unit until he is ready for a final mastery test on all important CO's. Meanwhile, the computer is generating a record of the student's progress at convenient points to provide a basis for individual decision making. Certain numbers of items are strategically placed in the testing sequence to yield theoretical confidence levels for certain decisions; e.g., at the conclusion of the segment for $CO_1$, the student achieves 100% on four test items measuring $CO_1$, the probability that he will be judged as "achieving $CO_1$, when in fact he hasn't, will be on the order of 15%."

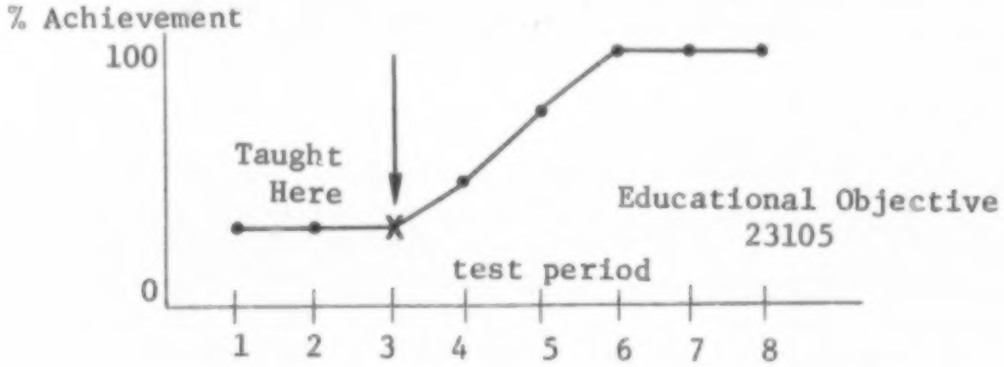
The utility of computerizing mastery testing procedures of the type in the foregoing example is found in: (a) the technical expertise which can be carefully applied to important decision points, not ordinarily applied in conventional teacher designed approaches to the problem; and (b) the near impossibility of maintaining the paper monster required to do the test scoring, record keeping, and summary reporting of student responses. Now that we are able to view the complexity of the processing programs, the developers built to computer monitor the mastery testing process. It is not at all surprising to note that few school's have attempted to handle the problem without some computer support.

We should further note at this point that,the model briefly shown for mastery testing is one of many possible applications. Since programs cannot be "turned around" overnight, the SPPED system was built in full recognition of the varieties of sophistication existing among local programs. Generally, the system can be applied to a program as it exists at a given point, but it is unlikely that the program will remain as it was at the point of introduction of SPPED, due to the discrepent information which will undoubtedly be generated.

## II: SPECIFIC PARTS OF THE SPPED

At this point, the general flavor of the SPPED system should have become evident and we can now proceed to the specifics. The heart of the system is composed of two so-called report generators: CAM and mastery testing. The first system, CAM, is designed primarily for program evaluation at a variety of levels, but is also useful for certain types of student monitoring. The mastery test report generator is designed for individualized student monitoring, but in a limited way, is also useful for program evaluation. The two system components, CAM and mastery testing, thus complement each other.

CAM can be further described as a highly efficient testing mechanism in that it involves application of item sampling. Recall that Gallup uses 1500 people in a national sampling design to generate statements about the attitudes and opinions of our entire nation. In a somewhat similar fashion, CAM uses data from a small number of people in a course to generate statements about performance in the course in general. Thus, by systematically assigning test items to samples of people, the CAM approach allows us to computer generate group performance data on an objective or unit at several different points in time. Two-to-three hours of testing of all students in a given course over a semester is thus made to yield large amounts of data for all important objectives in a course, in accord with the general model shown below:



Mastery testing, of course, is more familiar. The remaining parts of the SPPED system can be said to make application of the CAM and mastery report generators generally possible. Specifically, the parts of the SPPED can be briefly listed and defined as follows:

State Bank

Instructional Objectives at four levels

a. Terminal objective

b. Approximations to terminal objectives

c. Course objectives

d. Enabling objectives

It is only necessary to explain the first two levels of objectives, the latter two having already been described. Here is a "real" terminal objective:

0014400000

> Given a typical standard home dictionary (e.g., Webster's Collegiate Dictionary) and a specified word (e.g., "puree" or other unfamiliar word) the student will WRITE in his own words a definition of the word including all elements critical to the understanding of the word as given in the dictionary definition (e.g., Puree is a thick paste you make by rubbing cooked food through a sieve).

Based on a detailed study, the researchers defined terminal objectives (TO's) for reading which characterize the types of reading and related performances required of students in the secondary school. This type of performance should be exhibited by any student who takes the academic course of study in secondary school, and further, the reading program should enable it to be demonstrated. TO 0014400000 thus becomes a terminal behavior for the reading program, which has gone on some six to eight years, and is the basis upon which such a program can be evaluated.

Given that it is useful to have a standard for the "end" of a lengthy program (i.e., a TO), it seemed to us useful to determine whether this standard was approximated along the line, beginning at some point in the instructional program. For this we invented four levels of "approximations" to TO's, called ATO's, which would allow the local user to determine progress toward the TO. Level 3 for the above TO appears as follows:

0014400003

L. 3. Given a typed transcript of the definition of an unfamiliar work (e.g., puree) from a standard home dictionary, (e.g., Webster's Collegiate) and two simplified definitions of the word, one of which is correct and the other of which is incorrect, the student will SELECT the correct definition of the word.

The total of four levels of objectives included within the bank operates as program standards for different levels and functions in the instructional program. The TO's and ATO's function as the basis for the derivation of measurement procedures for evaluating the effectiveness of a program on an overall basis. In the reading area, there are some 225 such TO's and nearly 900 ATO's now available, divided into three sets: (a) the minimal set which presents universal standards for literacy; (b) the maximal set A which defines levels of reading performance required for entrance into secondary school; and (c) the maximal set B which defines standards for reading outside the context of formal education (e.g., How well must one read to relate effectively to a hobby magazine? A cookbook? The sports page of a newspaper?).

As stated previously, the CO's included in the BOIR constitute the standards for courses (end of a course), instructional packages, or checkpoints, as in individualized instruction. For example, one may have several CO's for division of whole numbers, with the lowest level CO constituting a statement about performance with division of one-digit number problems. Such CO's may be placed in relation to grade levels and function as standards of performance for grade 3, grade 4, etc., or they may be used simply as checkpoints for individuals as they proceed to the terminal point for division of whole numbers. The function of EO's, on the other hand, is to make explicit what an individual presumably must do to reach performance at a given CO level.

The state BOIR holds an index of the four levels of objectives described here. In the area of reading, we have already mentioned some 225 TO's and 900 ATO's. Included also, are some 500 CO's and 3000 EO's. In the future, a given TO will nest, not only a set of four ATO's, but sets of CO's within TO's and ATO's and EO's within CO's, resulting in a complete cross-classification of levels of objectives. Now, TO's and ATO's are cross-classified, as are CO's and EO's. These levels of objectives are further conveniently classified by topics, difficulty levels, grade levels, and other classifiers. Such classifiers allow the user to search the bank for the set specific to a given task. You may wish, for example, to obtain a set of phonics objectives, which are CO's, for the third grade. The bank will produce such a set with these classifiers or may produce an even more finite set based on a larger set of classifiers.

When your search of the state BOIR is completed, you are then ready to set up your own local bank of objectives, for which we will maintain a computerized index, allowing you to continuously add, delete and edit. This local bank also stores certain useful statistics on objectives, such as: Objective 23014 is generally achieved at the 80% level by fourth graders, at the 80% level by third graders, and at the 20% level by second graders. Other data may also be included to further characterize achievement on important objectives to support important curriculum decisions. This type of record will allow local personnel to develop reasonable expectancies for different types of children and will likely lead to extensive curriculum revision. The primary source of such data is the CAM system which generates quasi-continuous pretest, post test, and retention levels on all important objectives.

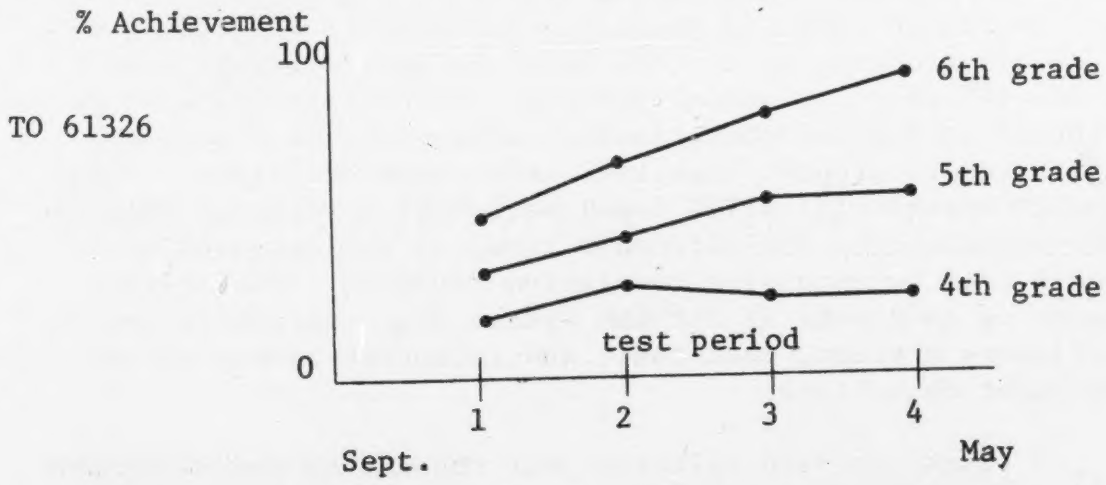
Once you have selected your objectives and developed your own modified local bank, the next step is to access the item bank, which now most often contains a half-dozen or more items for each objective. The test item component of the state BOIR is organized by objective (TO, CO, etc.) and by other classifiers (e.g., multiple choice versus completion-type items) and supports the generation of a local test item bank. The test item bank further allows adding, deletion, and editing, and stores statistics on items, allowing item refinement over time. This bank maintains an up-to-date record of all local items and tests, and can be coordinated with a local paper test file.

The remaining function of the BOIR is to support search and retrieval of instructional resources coordinated with CO's and EO's, and the indexing of local resources for the modified local bank. With the completion of a local resource bank, a teacher at the fourth grade level would be able to rapidly determine that there were nine resources available to teach EO 23014; two of these are designated as appropriate for students as remediation devices.

## III. EVALUATION MODELS

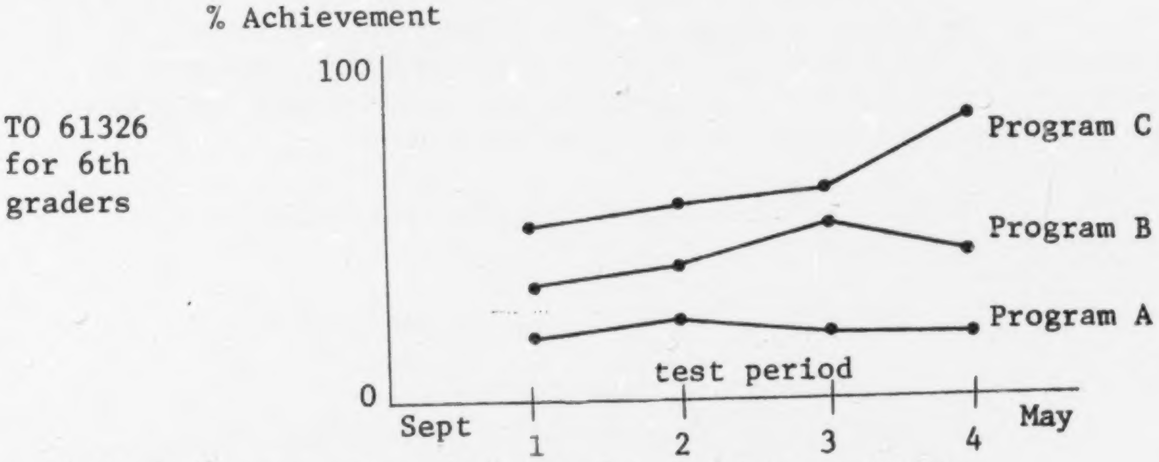
To greatly supplement (or replace) the limited management information available from standardized testing, the SPPED offers several evaluation models functionally integrated with instruction and levels of decision making.

a. Program Evaluation--Here CAM is applied to a sampling of TO's and ATO's at the upper-most grade levels of an entire program. Based on an initial selection of TO's (need analysis) a three to four-data-point design is implemented to yield performance data based on the application of item sampling. By the conclusion of the school year, longitudinal plots of the following type represent the changes in ultimate or terminal performance in a reading or math program as shown:



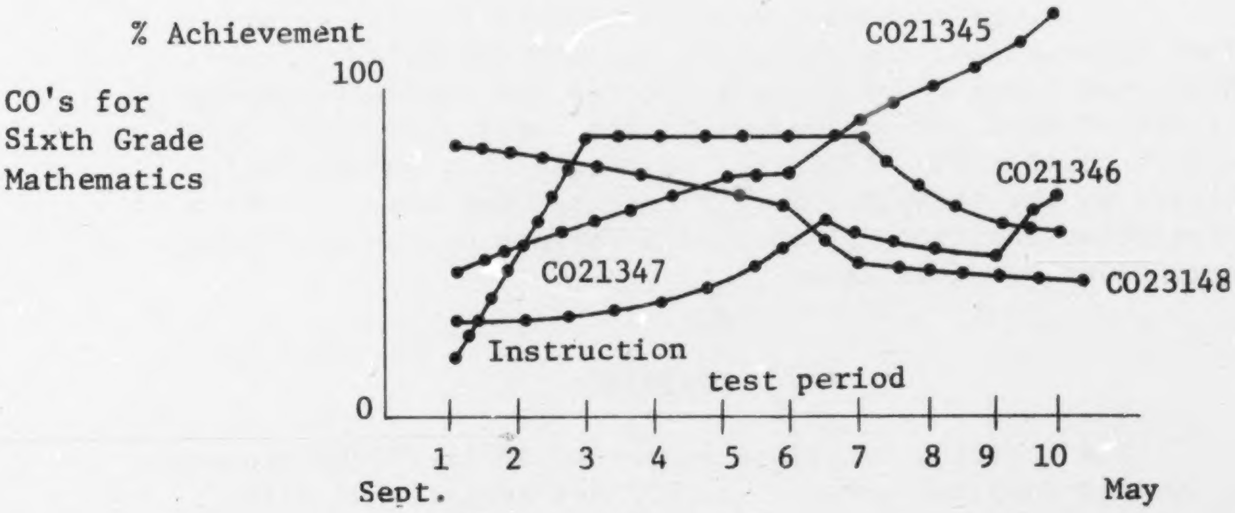
which for the reading program shows that TO 61236, an important skill relating to the ability to use a dictionary in a generalized fashion, takes hold in grade five, and is achieved by nearly all students sampled in grade six. Given this type of data, it is safe to say that students leaving the reading program will be able to handle the dictionary skill requirements in the secondary school (TO 61236 was presumably derived from performance requirements in secondary school).

If more than one program were available to achieve the same TO, i.e., you have at least two or more different reading programs, the following display would be possible:



And, this type of processing and display could be accomplished via CAM for no more than you are now paying for standardized achievement testing and without increasing testing time.

b. Sub-program Evaluation--For any level, e.g., grade level, within a program, it is customary to generate from 15 to 20 data points in CAM applications. The resultant data allow teachers within levels to modify the program in progress and further provide the basis for an annual revision of the program, level by level. The varieties of program data made available allow for articulation between and within levels in a program, as in the following:



Course objectives 21345-23148 were all taught between test periods two and three; the resultant data show a high level of success only for CO 21345, suggesting the need for modification in the course.

c. Overall Student Evaluation--For individual students, CAM generates the same type of profile as is made available for the program and subprogram levels. Such profiles have been useful in estimating the extent to which a given student is continually progressing relative to himself.

d. Mastery Evaluation--The levels of evaluation which can be made available may be made somewhat apparent by two contrasting models. In modularized or packaged instruction, a computer supported sequence might be:

1. Module pretest for six learning activity packages.
2. Go to modules 1, 3, 5, 6, in that order.
3. At end of LAP 1, take LAP post test 1, at end of LAP 2, take LAP 2 post test, etc.
4. At conclusion of all LAPS, take module post test.
5. Go to enrichment LAP 1-A, go to module 2, go to remedial LAPS 1-A, B, etc.

In group-paced instruction, the testing sequence would reduce to pretesting and post testing on all important CO's for a unit, with possibly some remediation and remedial testing. A variation on this theme allows teachers to continually regroup within a level for students who fail parts of units at any given point throughout the course.

In a current application of mastery testing to modularized instruction, the computer, located centrally in the school, may receive one or more records per student each day. A record of day-to-day progress is thus maintained with the computer continually "flagging" objectives not successfully achieved by the student. Such "flagging" may also include a prescriptive function, given that a variety of instructional alternatives are available.

## IV: TRAINING

The training functions supported in the SPPED project are divided into two areas: (a) EDP for educational data processing, and (b) system training in the use of such systems as CAM, mastery testing, banking, and such supporting functions as choosing and modifying objectives.

Depending upon the level of the SPPED application in the school, training may take as long as 50 to 60 hours. Such training as is available is strictly functional in relation to implementation of the system: a teacher learns how to modify objectives and use the state BOIR and then submits requests for objectives; or, a teacher learns how to read, interpret, and act upon CAM data, and then shortly begins to receive CAM data on her own class. The SPPED training materials are further designed to require a minimum of consultant intervention, being in the form of programmed materials, guidance materials, simulations, and supplementary reading. The training materials now available will result in fairly extensive modification of teacher, student and administrative roles in the direction of greater involvement in management functions.

For EDP, a sampling of training functions includes:

1. Form completion

2. Maintaining quality control in procedures for recording student responses

3. Checking computer output

4. Processing requests

For systems training, a sampling of training functions includes:

1. Need analysis

2. Formulating local program goals

3. Selecting, modifying, and stating instructional objectives.

4. Designing instructional programs

5. Generating appropriate local models for applications of CAM and mastery testing.

6. Interpreting CAM and mastery test data

7. Making decisions about programs and individuals on the basis of test data

8. Working in teacher and administrative peer groups to improve programs

9. Modifying programs

10. Developing a local bank of objectives, test items, and instructional resources

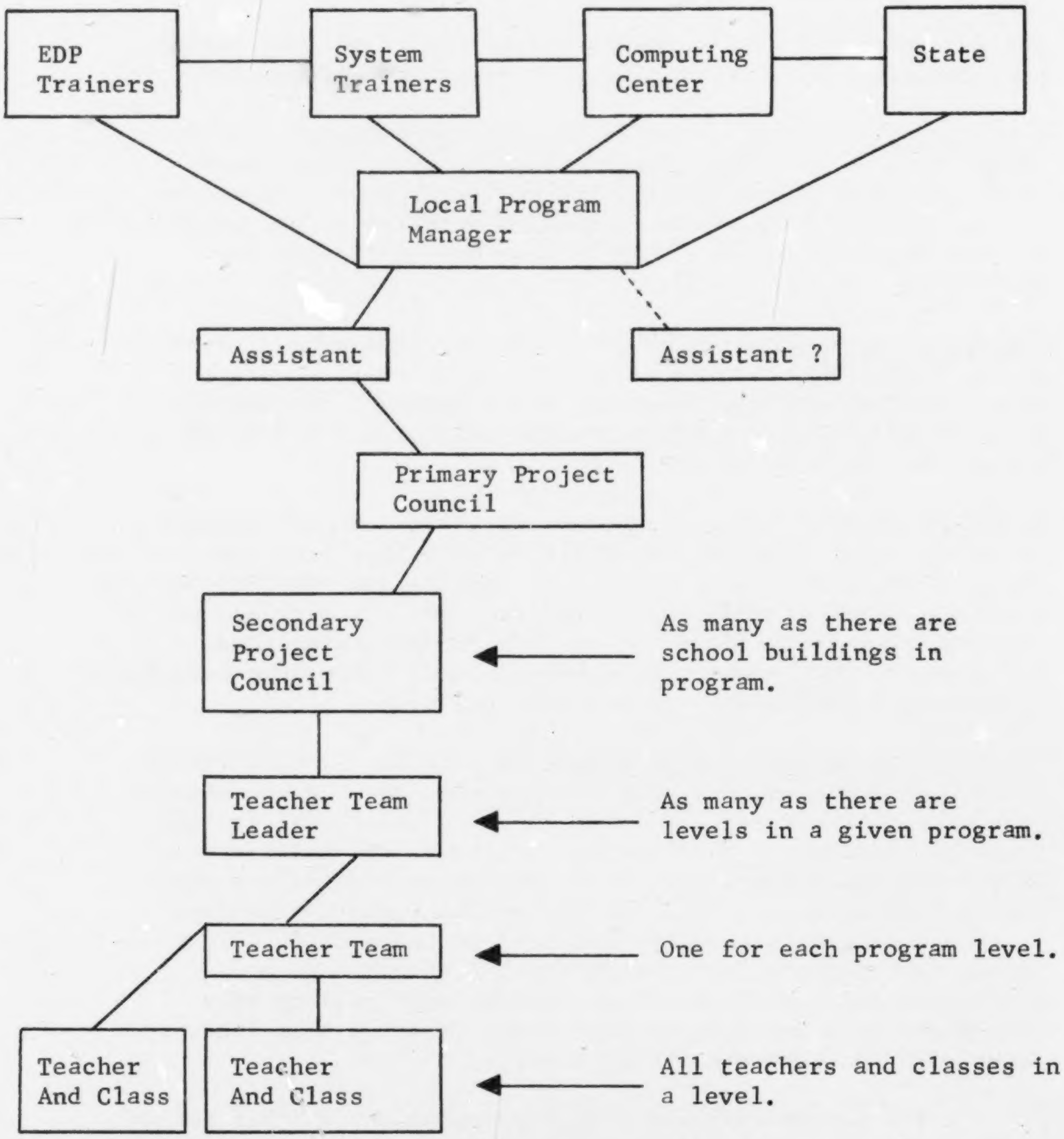
These and other training functions are handled through the use of separate instructional modules which can be grouped for particular audiences, such as teachers, students, parents, administrators, and curriculum coordinators.

## V: ORGANIZATIONAL STRUCTURE

An effective application of the SPPED requires some restructuring of roles in the school and may also require the introduction of new personnel. One possible organizational chart, reflecting experience in applications of CAM, appears on the next page.

A sampling of the responsibilities for each box in the foregoing chart and the associated personnel makeup follows the chart.

## STAFFING STRUCTURE FOR SPPED


EDP Trainers
System Trainers
Computing Center
State
Local Program Manager
Assistant
Assistant ?
Primary Project Council
Secondary Project Council
As many as there are school buildings in program.
Teacher Team Leader
As many as there are levels in a given program.
Teacher Team
One for each program level.
Teacher And Class
Teacher And Class
All teachers and classes in a level.

EDP Trainers--a consultant who sets up all procedures for data processing and associated training in the schools. Trainer sets up training functions to be implemented by LPM (local program manager), for example, he shows the LPM how to train teachers in checking IBM mark-sense cards used by students.

System trainers--a consultant who sets up all system training procedures and shows the LPM how to plan and implement training; assists in training.

Computing center--does all data processing, delivers reports to LPM for distribution, maintains local bank.

State--supervises entire operation, maintains quality control, provides materials, designs overall plan for implementation.

Local program manager--manages the implementation of the project, installs training, monitors training, monitors local data logistics, communicates with trainers, computing center, state, councils, and teacher teams on problems at any point in the system operation. LPM is accountable if anything goes wrong.

Primary Project Council (PPC)--a district wide council composed of the LPM, 1-3 upper administrative staff, teacher leader representatives, parents, and students. Responsible for formulating long-range plans and policy, and reviewing the recommendations of the LPM.

Secondary Project Council (SPC)--a building council composed of teacher team leaders, the building principal, the LPM, 1-3 parents, and students. For the application of SPPED in a building, SPC coordinates activities, reports problems to LPM, monitors installation of project, communicates needs and plans to PPC, meets with parents, takes corrective actions, formulates building policy, reviews team plans.

Teacher Team Leader-Teacher Team--led by a master teacher for a level within a program, the teacher team reviews and selects objectives, structures curricula, selects materials, designs programs, interprets data, makes individual and instructional decisions, and communicates with the SPC concerning its plans and recommendations. Team leaders may be further organized to insure program components designed by teams at different levels fit together into a complete and smooth sequence of objectives and activities (e.g., the primary reading team interlocks with the intermediate team, which in turn interlocks with the secondary level teams).

The person with the most responsibility in this set-up is the LPM. Former curriculum coordinators may be appropriate for this task, and here it may be said that such a position can be fully justified by the potential effects of conducting the task adequately. Prior work with teacher teams and LPMs had eventually resulted in wholesale modification of curricula with substantial positive effects on student performance. In one setting, number of "approved" instructional objectives were removed on the basis of very low performance and irrelevance.

## VI: DATA PROCESSING

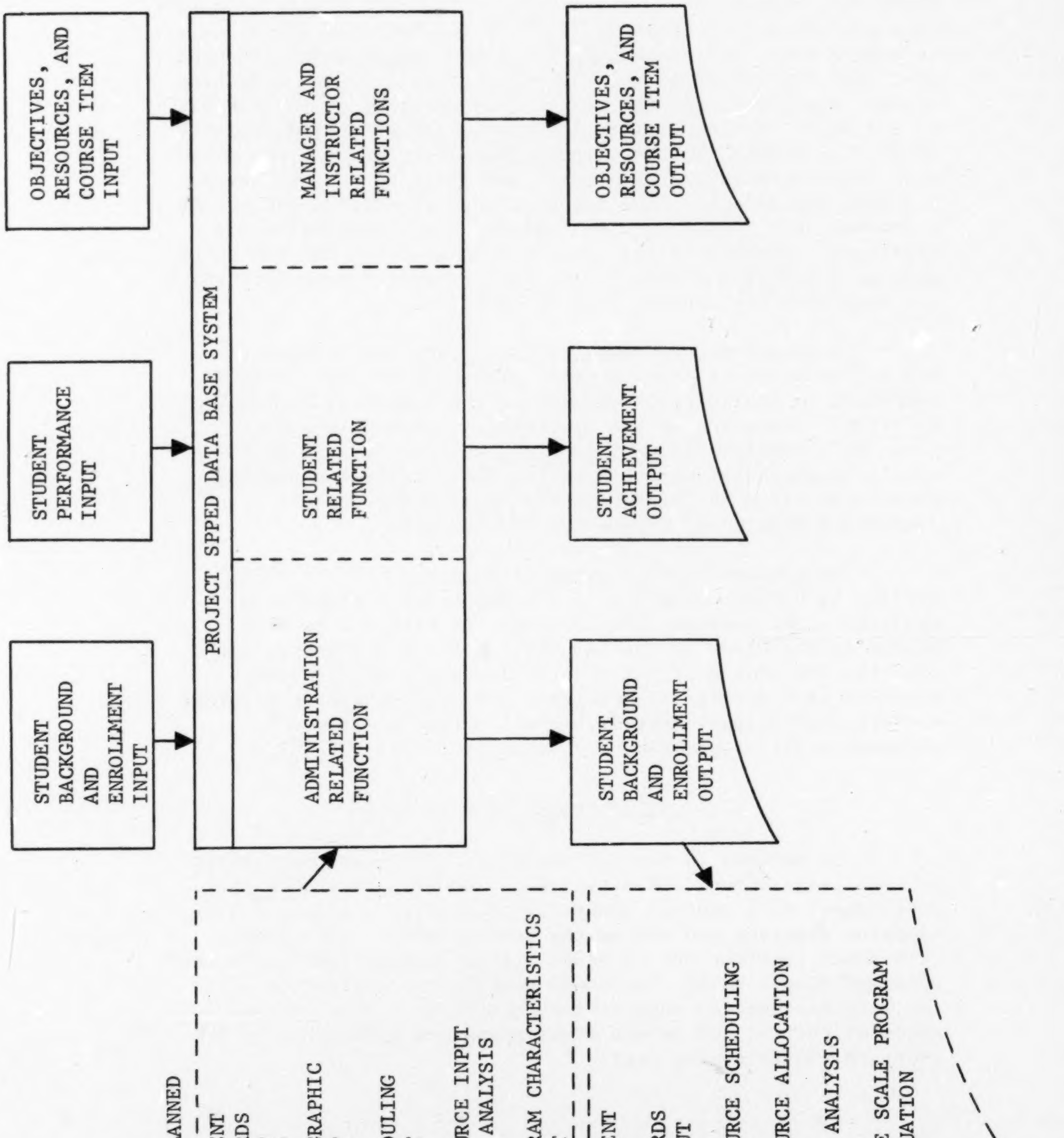
Currently, there are two basic procedures for delivering SPPED data processing to the schools. The most widely used mode is a central data processing facility located near the school. In such a case, all processing is in the "batch mode", meaning that jobs are delivered on a day-to-day basis to the computing center, processed, and the results are returned to the schools in 1-3 days. The capability for remote job entry and delivery (RJE) also exists, but involves higher costs in that the school must lease or purchase high speed terminals to support entry and printing of data. The RJE procedure is still a batch mode operation, but avoids the problems of data transmission via messenger. Given a fairly large volume of data, the RJE batch mode is a viable and potentially cost effective procedure which can substantially improve turn-around time.

A second method involves buying your own computer. N.Y.I.T. researchers have experimented with the use of mini-computers in applications of many of the functions included in SPPED. Depending on the availability of knowledgable personnel locally, the mini-computer application can be the most cost-effective approach to the data processing problem. Visitation sites for mini-computer applications are at Jamesville-DeWitt and Greece Central Schools.

The present set of computer programs for the SPPED project is being maintained in a large central processing facility. The programs are designed for transfer to computers on the order of the IBM 360, model 40 and above, and are, for the most part, written in languages which allow transfer to a variety of machines. The mini-computer programs are yet restricted to use in Digital's PDP-12 (4K-core), although modified programs are being prepared in BASIC.

## VII: FUTURE DEVELOPMENTS

In process is the initiation of SPPED data processing in facilities around the state (e.g., BOCES), including the development of a central processing facility to maintain all computer programs and act as the central BOIR. Involvement with other institutions in other states is projected, with the presumed result being a national banking and evaluation facility designed to support instruction on a broad basis. Areas of current and future development are summarized in the chart on the following page.


STUDENT BACKGROUND AND ENROLLMENT INPUT
STUDENT PERFORMANCE INPUT
OBJECTIVES, RESOURCES, AND COURSE ITEM INPUT
PROJECT SPPED DATA BASE SYSTEM
ADMINISTRATION RELATED FUNCTION
STUDENT RELATED FUNCTION
MANAGER AND INSTRUCTOR RELATED FUNCTIONS
STUDENT BACKGROUND AND ENROLLMENT OUTPUT
STUDENT ACHIEVEMENT OUTPUT
OBJECTIVES, RESOURCES, AND COURSE ITEM OUTPUT
PLANNED
STUDENT RECORDS INPUT
DEMOGRAPHIC INPUT
SCHEDULING INPUT
RESOURCE INPUT COST ANALYSIS
PROGRAM CHARACTERISTICS INPUT
STUDENT
RECORDS OUTPUT
RESOURCE SCHEDULING
RESOURCE ALLOCATION
COST ANALYSIS
LARGE SCALE PROGRAM EVALUATION

## VIII: LIMITATIONS

Over the next several years, the SPPED system components will be subjected to continued refinement. In areas such as reading, for example, it will be at least three years before a relatively refined bank is available, along with supporting data. At this point, however, the objectives included in the reading bank are very probably as good as any comprehensive set available. Thus, the objectives and other material now available should have some reasonable level of utility until a better product can be developed. In fact, there appears to be no end to the task of refining the contents of the BOIR. The SPPED project initially started with one level of objectives; on the basis of experience, there are now four levels. The user research being planned for implementation of the system will undoubtedly uncover more levels and additional refinements needed.

In certain areas of banking, the task to be completed is massive. In the reading section of the BOIR, approximately 25% of EO's will be associated with instructional resources. For all other areas of the BOIR, the resource search function will not be operational until a way is found to generally support cataloging of appropriate instructional materials. The resource banking function is thus, at this point, one which must be handled at the local level.

There are certain other areas which will continue in various phases of research and development in the near future. For example, our laboratories are now experimenting with the computer generation of objectives. Item analysis procedures are just now in the process of design for eventual application in the BOIR, and this effort will shortly result in substantial modification to the existing banking programs. There is yet a considerable amount of research to be done on the reading TO's, an effort which constitutes an entirely new development in the area of reading. Questions relating to these and other areas of development within the SPPED project will receive more answers as experience is gained through research and implementation.

## DISSEMINATION AND VISITATIONS

Numerous releases have been distributed to the news media explaining the nature, goals, and progress of the contract awarded to NYIT by the Office of Education. These descriptions together with many presentations by the principal investigator and other officers of the project to educational convocations have generated an interest in the program on the part of local school districts and institutions of higher learning throughout the country.

Continuous visitations have been welcomed by New York Institute of Technology to discuss the concepts, objectives, strategies, and development of the project. Escorted lecture tours of the computer and classroom facilities, where the course operations are observed, have been conducted as a weekly activity. The visitors have been members of boards of education, principals, chairmen and classroom teachers representing a large percent of the local school districts.

Several Signal Corps and Air Force Base installations, attracted by the reports of the accomplishments achieved under the contract, have sent groups of staff members on inspection and exploratory missions to NYIT. Small groups of touring educators from foreign countries have also found their way to this campus and have observed and discussed the merits of the project. Leading educators from Japan, India, Algeria, Israel, South Africa, Nigeria, Netherlands, Indonesia, Sweden, Italy, France, Venezuela, and Canada have all been received hospitably.

Correspondence has been received from educational and commercial institutions throughout the world requesting information and samples of the materials generated under the project. Materials and instructions for the various model courses have been provided to Shaw University, Bowie College, Springfield Technical Community College, United States Naval Academy at Annapolis, Glen Cove High School, New York, and Forest Hills High School, New York.